DARPA

TWENTIETH SYSTEMS & TECHNOLOGY SYMPOSIUM

Charging Ahead into the Next Millennium

DARPATech '99

Denver • June 7-10, 1999

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DARPATech '99
Welcome and Overview

Dr. Frank Fernandez
Director, DARPA

June 8, 1999

In The Future, Institutions Must *Simultaneously* Pursue:

- Systematic, continuing improvement
- Building tomorrow's systems based on a proven today
- Radical innovation with a goal that makes obsolete and, to a large extent, replaces even the most successful current products

Strategy

- Flexibility to find, exploit externally generated ideas is paramount
- High technical risk, high-focus investments
- Competition
- Investment-oriented focus

Approach

- Broader horizon than commercial analogues
- More focused than university research
- Not bound by military requirements
- Flat, small organization
- No facilities, themes
- Rotate programs, staff

Operational Dominance

- Execution Based Planning
- Affordable, Precision Moving Target Kill
- Mobile, Distributed Communications
- Combined Manned and Unmanned Warfare

High-Risk Technology Exploitation

- Core Technologies
- The Intersection of Biology, Information and Microsystems

Reorganization

- Flatten organization . . . emphasize bottoms-up, opportunity-driven nature
- Emphasize thrust areas

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Office Structure

Director
Frank Fernandez

Deputy Director
Jane Alexander

Advanced Technology Office
T. Meyer
W. Jeffrey

Microsystems Technology Office
N. MacDonald
E. Urban

Defense Sciences Office
L. Dubois

Special Projects Office
J. Carlini
A. Alving

Information Systems Office
W. Mularie
B. Sharkey

Tactical Technology Office
D. Whelan
A. Adler

Information Technology Office
D. Tennenhouse
B. Hui

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Consider Joining the DARPA Program Management Team

Biological Warfare Defense and Biological Systems

Dr. Jane A. Alexander
Deputy Director

BWD is *Very* High Priority

Why?

- Protect military troops, airfields, ports, depots
- Prevent, mitigate terrorism against population centers
- Bioengineering technology may lead to new pathogens

Biological Primer

Bacteria, Viruses, Toxins are quite different

- **Size of agent particle**
- **Modes of action in the body**
- **Effects can be lethal to incapacitating**
- **Time for symptoms to appear**
- **Size of dose needed for disease or death**

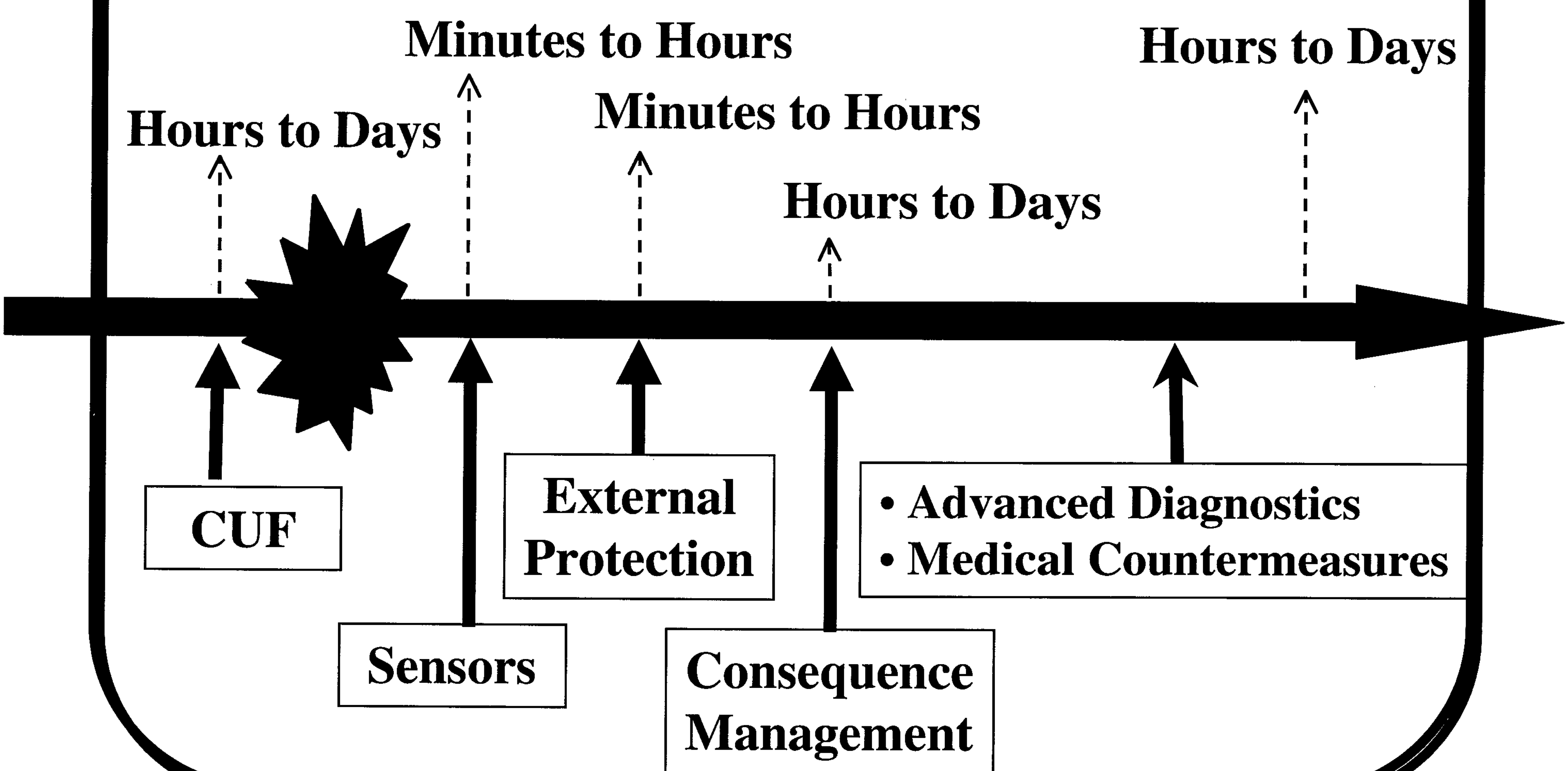
Bioengineering Problem

- Antibiotic resistant (bacteria)
- Disguised pathogens
- Non-pathogens turned into pathogens
- Enhanced infectivity
- Enhanced stability in environment
- Changed route of infectivity
- Increased production yield (toxins)

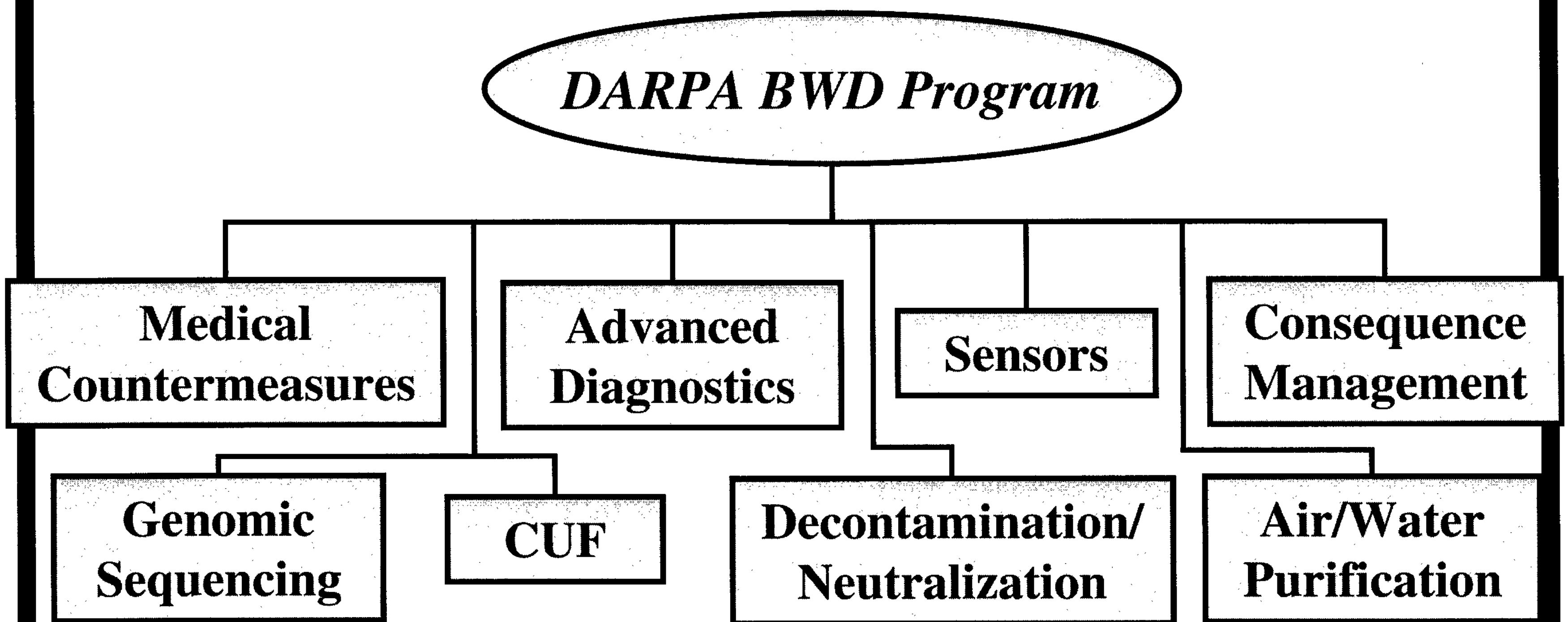
BWD at DARPA

Goal: **Thwart the use of biological warfare agents (including bacterial, viral, and bioengineered organisms and toxins) by both military and terrorist opponents**

BWD Program Overview



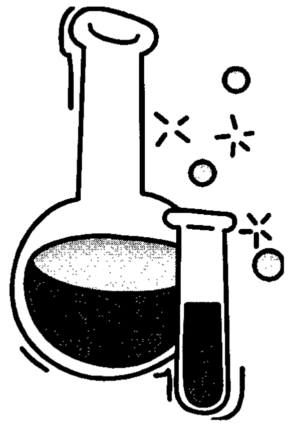
BWD at DARPA

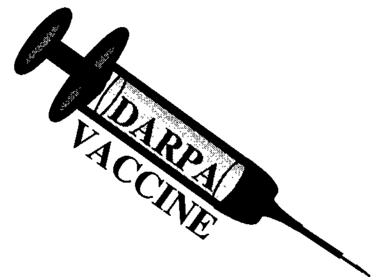

DARPA BWD Program
Medical Countermeasures
Advanced Diagnostics
Sensors
Consequence Management
Genomic Sequencing
CUF
Decontamination/ Neutralization
Air/Water Purification

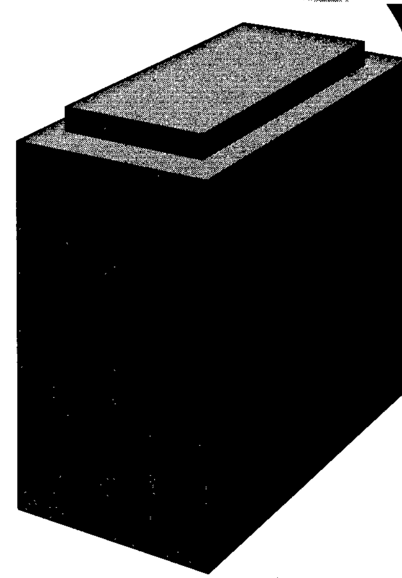
Biosensor Objective

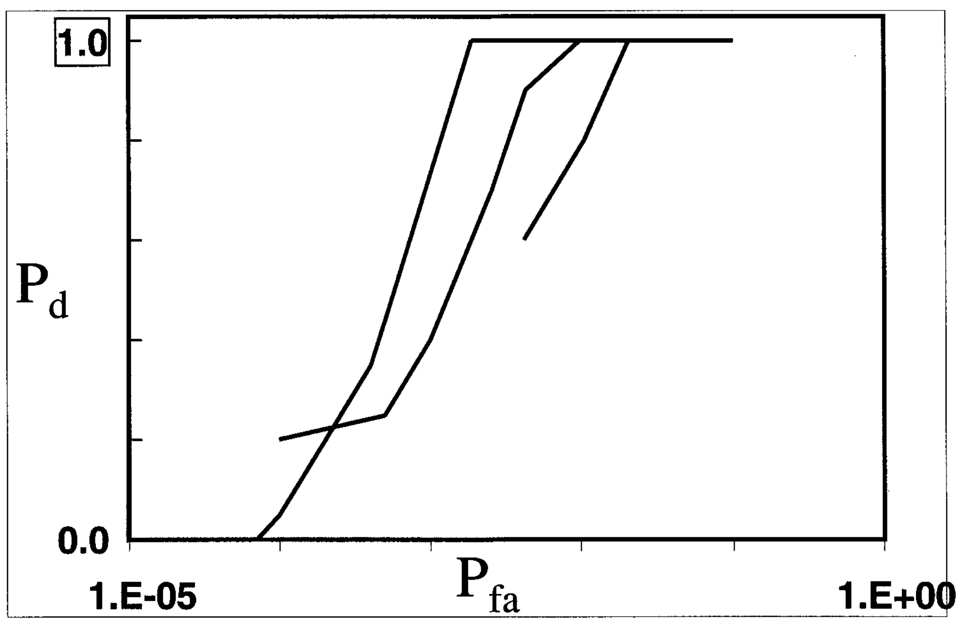
- Fieldable (Small, Low-Cost)
- Integrated
- Live vs Dead
- Unattended

BWD Systems









Operational Impact of Information Management

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The Information Problem:

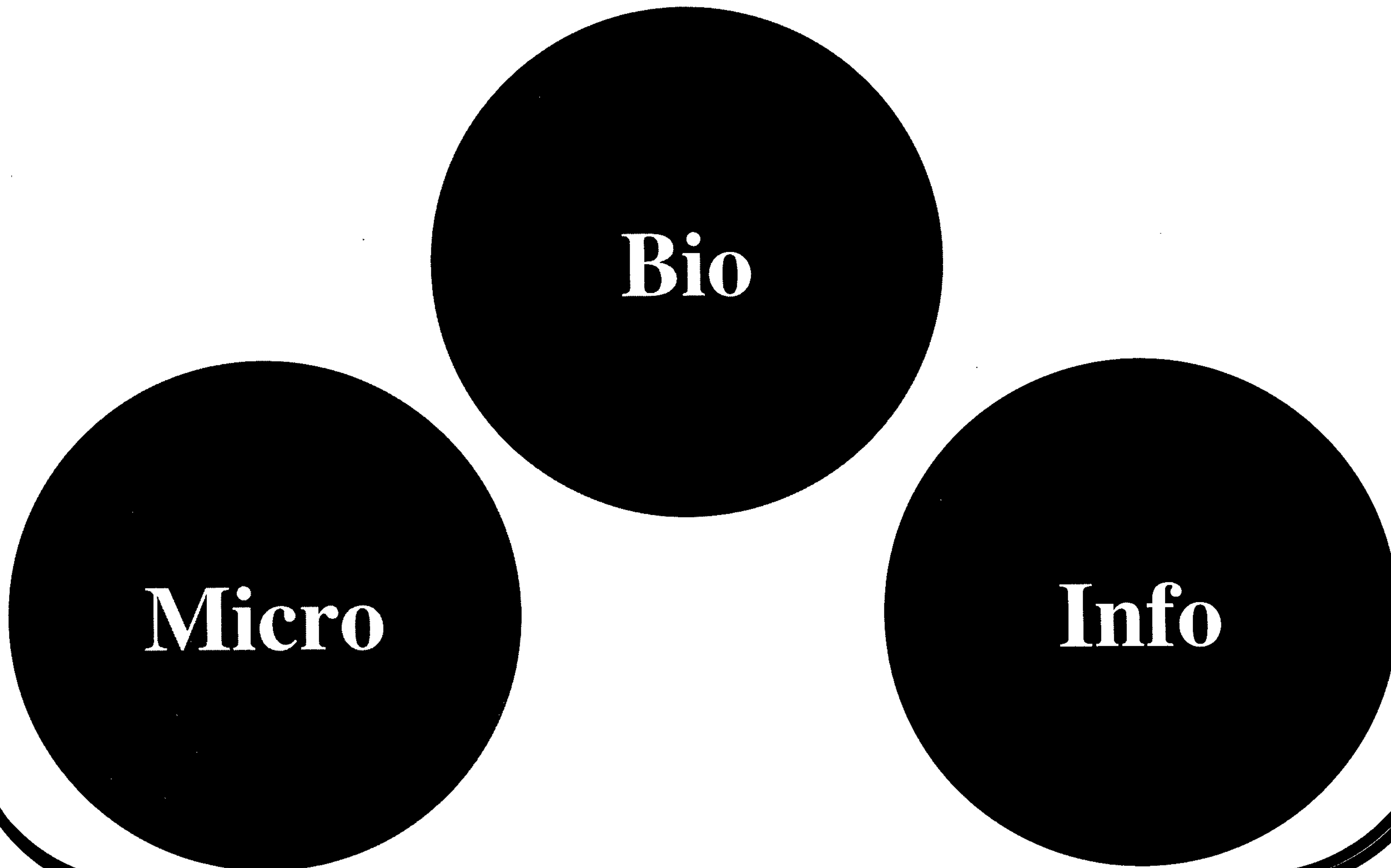
- Managing consequences of a terrorist attack is very complex
- What to do is not well known - hard to find the "few who know"

ENCOMPASS Components

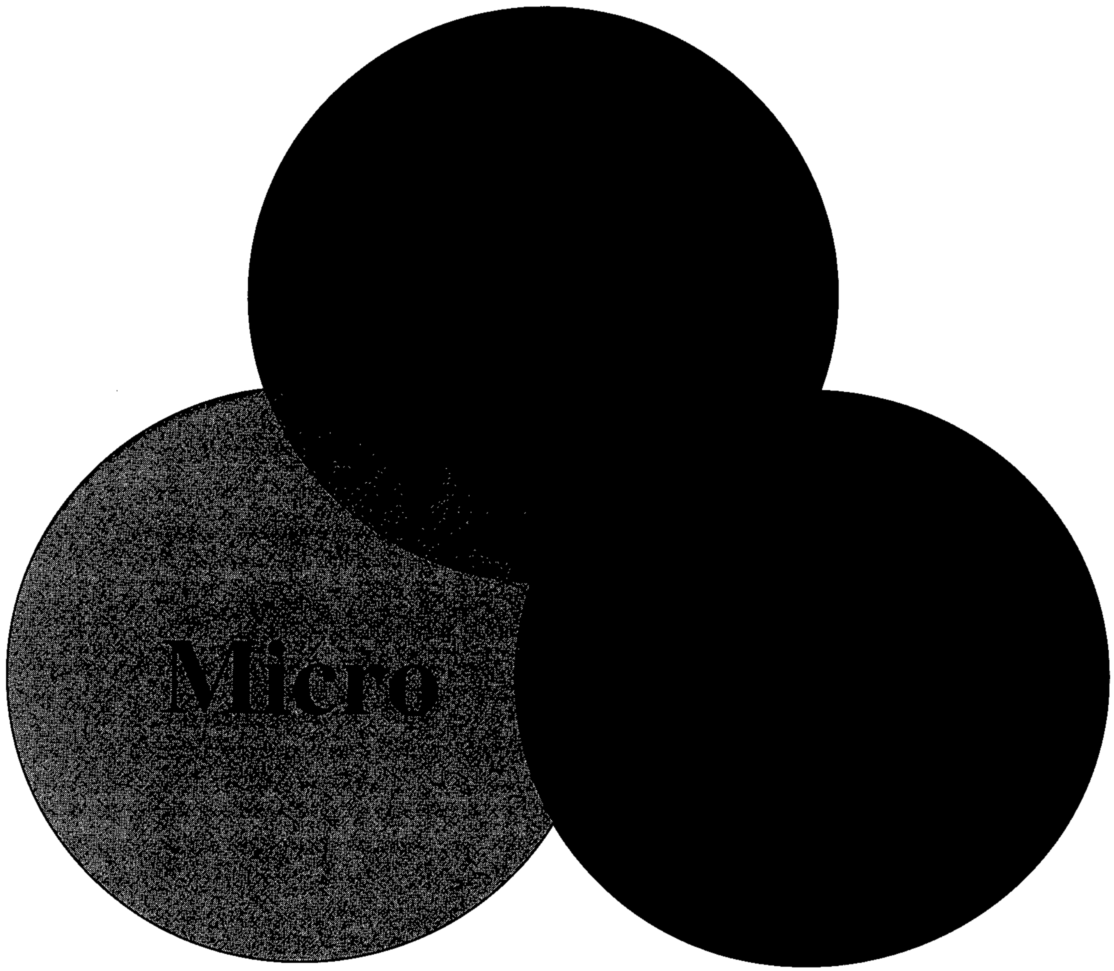
ENCOMPASS Components

- Electronic PlayBooks
- Incident "Repository"
- Electronic Watchboard
- Patient/Casualty Tracking
- ViewPort
- CODA/BASIS
- Casualty Management

[Bio:Info:Micro] Interface



Interface of Biology With More Conventional DoD Technology



Controlled Bio Systems

Control, influence, or mimic the locomotion and distribution of biological organisms for sensing, reporting and countermeasure delivery

Biotic Control	Control through Biointerfaces	Biomimetics

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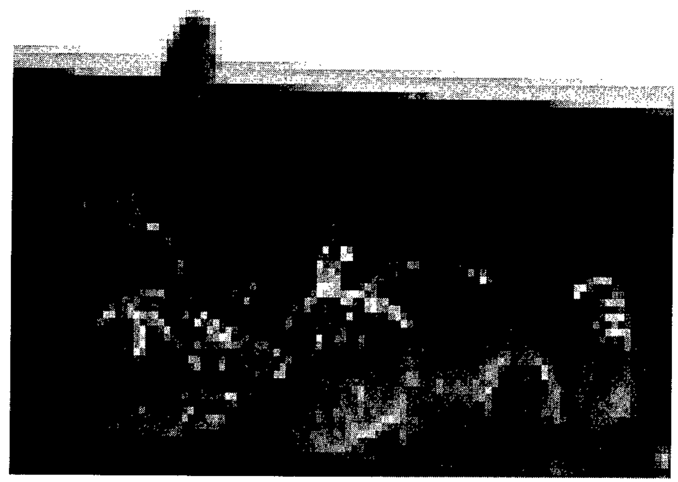
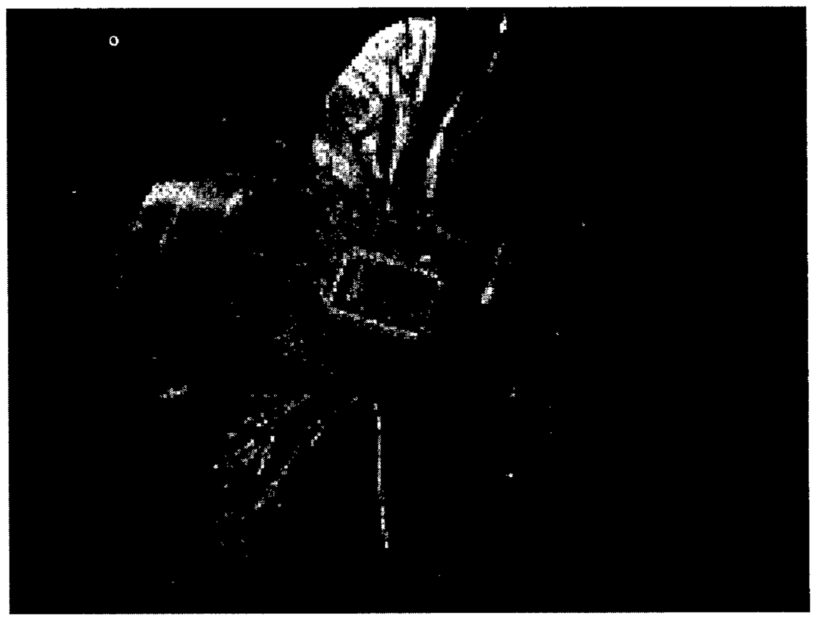
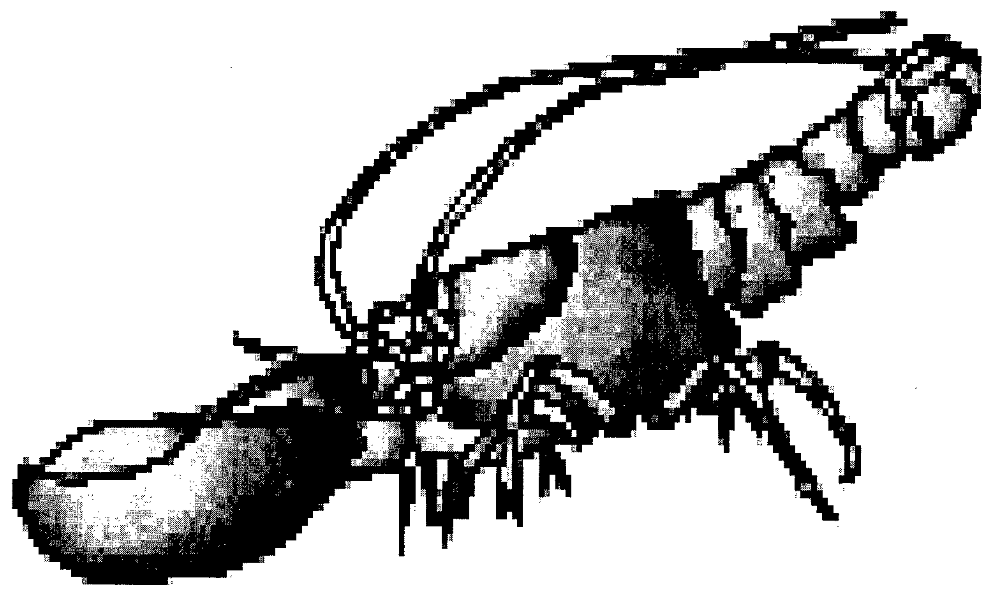
Biotic Control



Control through Biointerfaces



Biomimetics



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Electronic Dog's Nose

Defense Sciences Office

Office Overview

Lawrence H. Dubois
Director

http://www.darpa.mil/DSO/

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DSO: *Mission*

"Technology Harvesting"

Identify and vigorously pursue the most promising technologies within the science and engineering research communities and develop them into new DoD capabilities.

DSO: *In Practice*

Respond to technological opportunity

- "*Miracle Identification*"
- *Catalyze* the creation of new technologies
- Clear understanding of military needs

Multidisciplinary technical approach

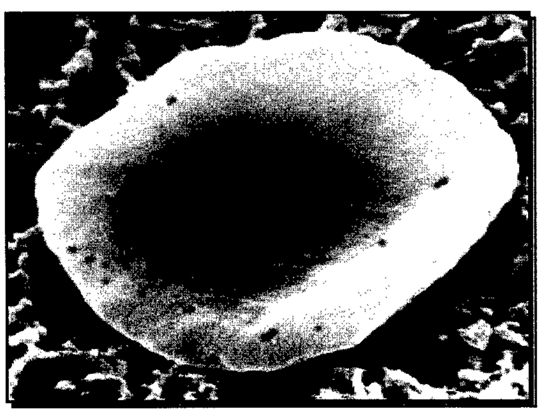
- Office is technically diverse
- Seek opportunities at interfaces between conventional disciplines
- *Teaming*

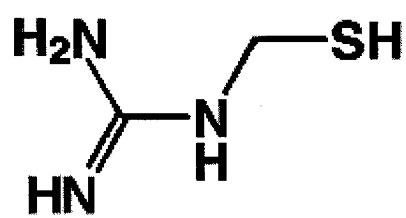
DSO: *Technology Thrusts*

- Biological Warfare Defense
- Biology
- Defense Applications of Advanced Mathematics
- Materials and Devices for New Military Capabilities

Biological Warfare Defense

- Medical countermeasures
- Advanced diagnostics
- External protection
- Consequence management
- Genomic sequencing





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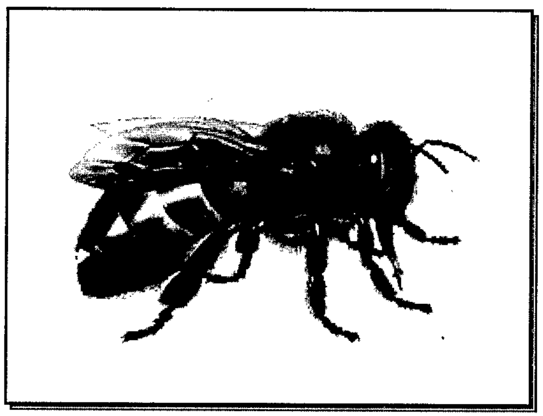
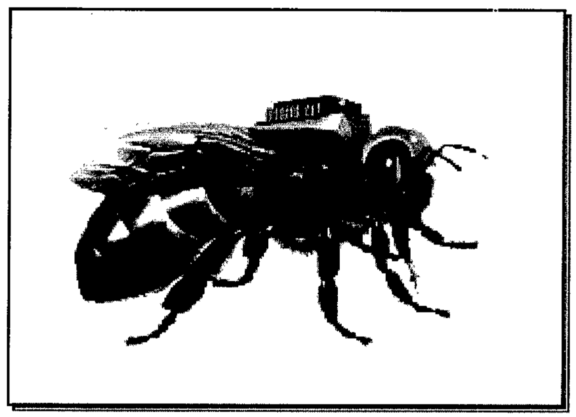
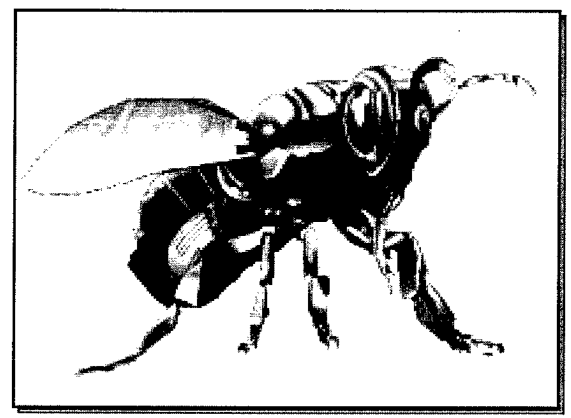
Biology

- Tissue-based biosensors
- Controlled biological systems
- Bio-inspired systems
- Biomaterials / bioprocessing

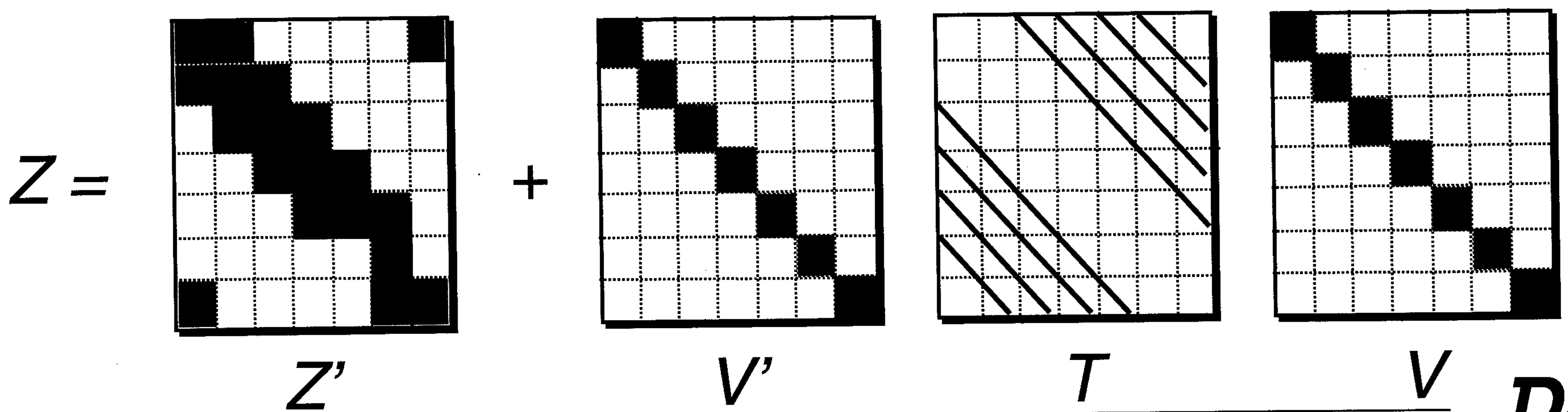






Advanced Mathematics

- Signal and image processing
- Electromagnetic computations
- Fast and scaleable computational algorithms
- Optimized micro-structural process control for thin film growth



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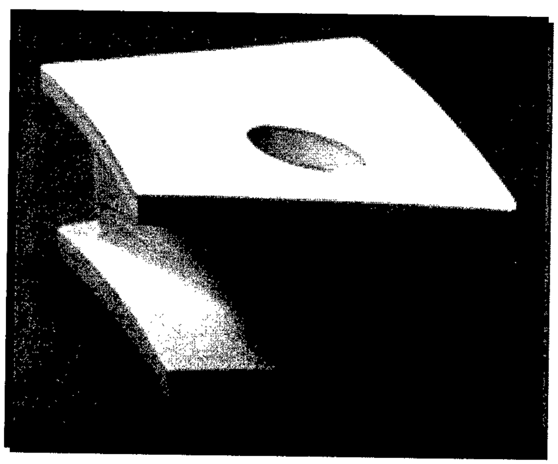
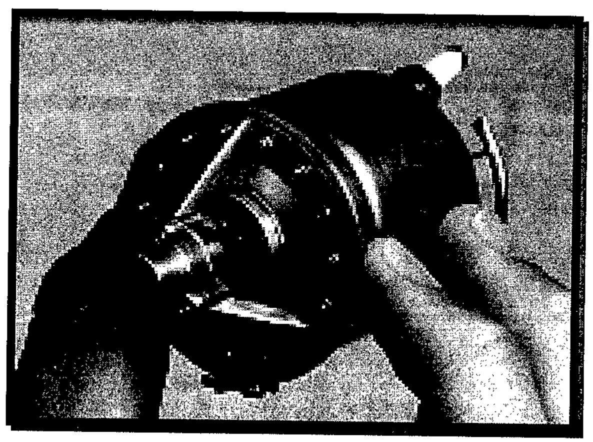
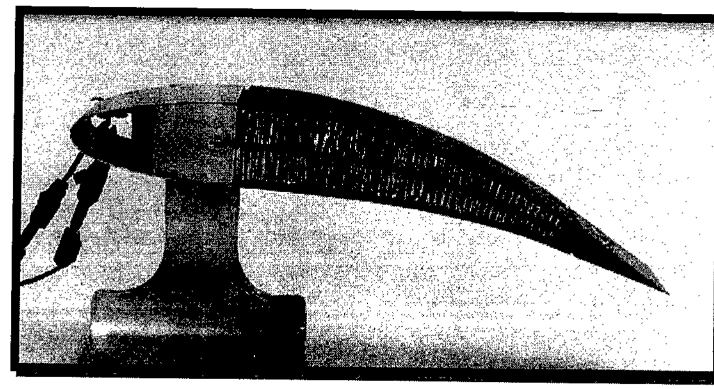
Materials and Devices

- *Functional* materials and devices
- *Smart* materials and demonstrations
- *Structural* materials and components
- Mesoscopic machines
- Power generation and storage







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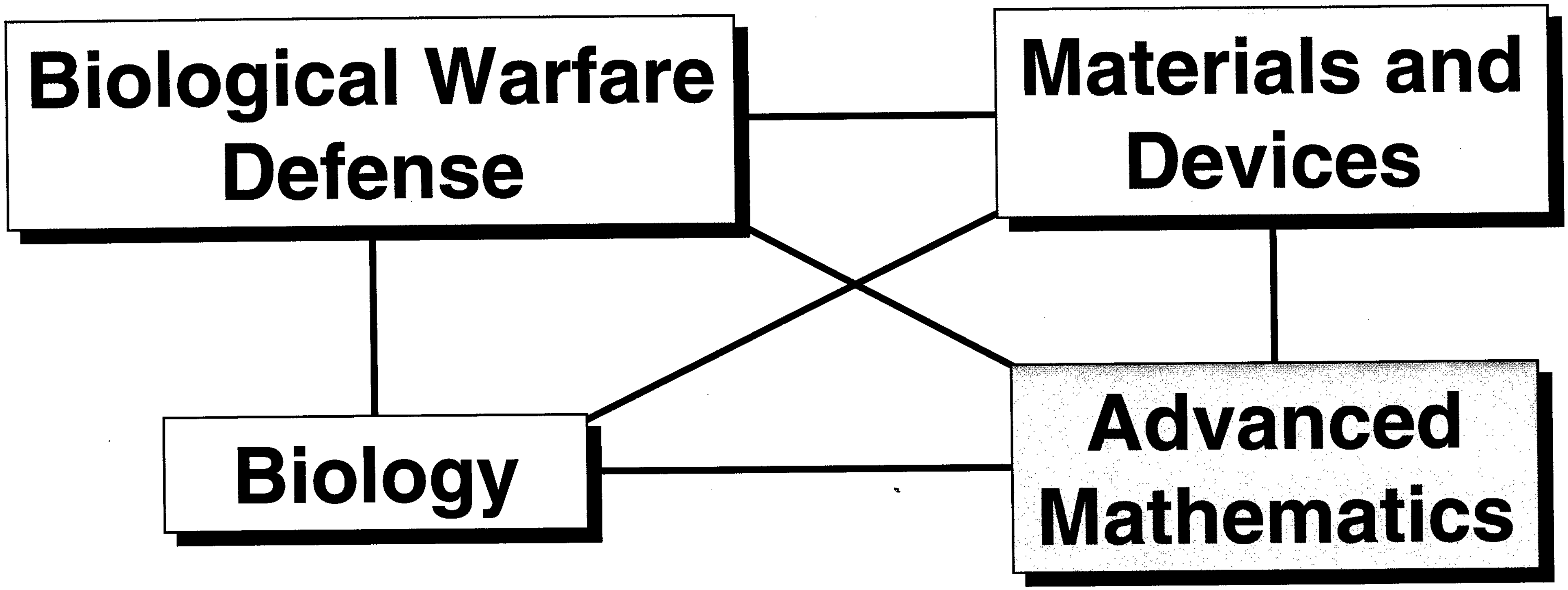
DSO Program Synergy



Developing New Ideas

Biological warfare defense

Biomolecular systems

Virtual electromagnetic test range

Meso - 2000

Compact hybrid power systems

Accelerated materials acceptance

New materials / processing concepts

Other <u>really</u> cool stuff!

http://www.darpa.mil/DSO/solicitations/

DSO

Biological Warfare Defense at DARPA Program Overview

Stephen S. Morse, Ph.D.
DARPA/DSO
smorse@darpa.mil

DARPA BWD Program

<u>Goal</u>: Develop and demonstrate technologies to thwart the use of biological warfare agents (including novel or bioengineered pathogens) **by both military and terrorist opponents.**

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DARPA BWD Program

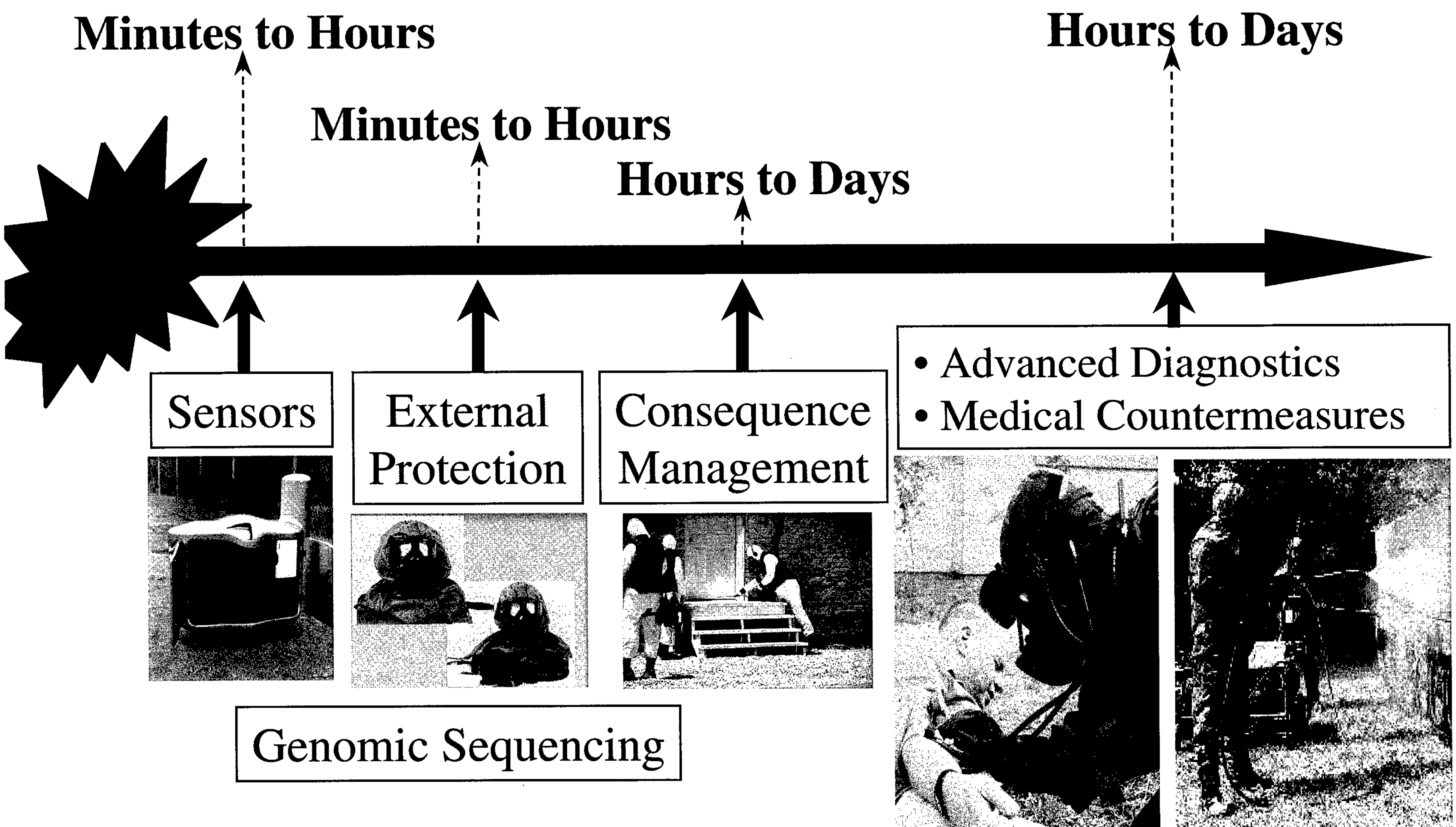
Approach: Create technologies applicable to broad classes of pathogens and toxins (most current techniques are agent specific).

DARPA BWD Program

Measures of Success:

- *in vivo* testing (vs. *in vitro*)
- live agent (vs. inactivated)
- significant pathogen/toxins (vs. simulants)
- integration and utilization

BWD Program Overview



DARPA BWD Program

Sensors
Dr. Mildred Donlon
Dr. Alan S. Rudolph
Dr. John K. Smith

Advanced Diagnostics
Dr. Stephen Morse

Medical Countermeasures
CDR Shaun B. Jones, M.D., USN

External Protection
Dr. William Warren
CDR Shaun B. Jones M.D., USN

Genomic Sequencing
Dr. Ira Skurnick

Consequence Management
Col John Silva, M.D., USAF

BWD Program Overview

External Protection

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External Protection

Thermo-Catalytic Approach to "Clean Air"

- Pass hot air thru catalytic reactor to destroy lethal agents
- Heat & cool air in meso-heat exchangers
- Small, lightweight

"Artificial Skins"

Coat polymer scaffolds with high surface area aerogels incorporating enzymes to promote biocatalysis

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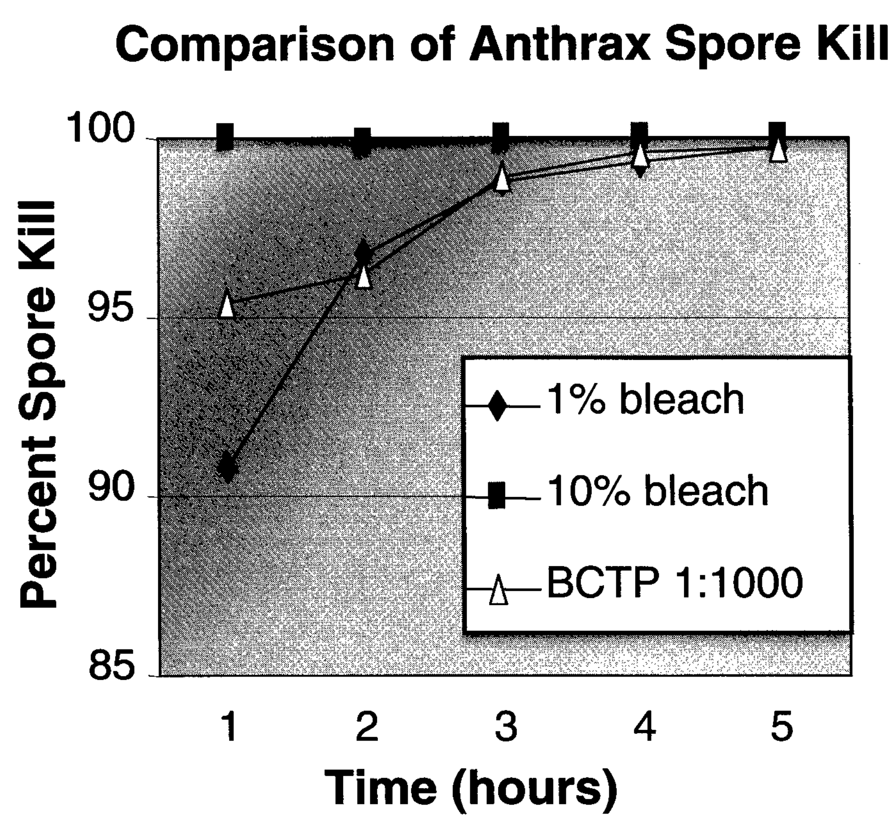
DARPA Nanomolecular Countermeasures

- Novasomes™ have significant bactericidal effect (> 99% killed) on gram positive bacteria and spores
- Novasomes™ can be used to decontaminate vehicles and sensitive equipment
- Novasomes™ are non-toxic to humans, plants, and animals



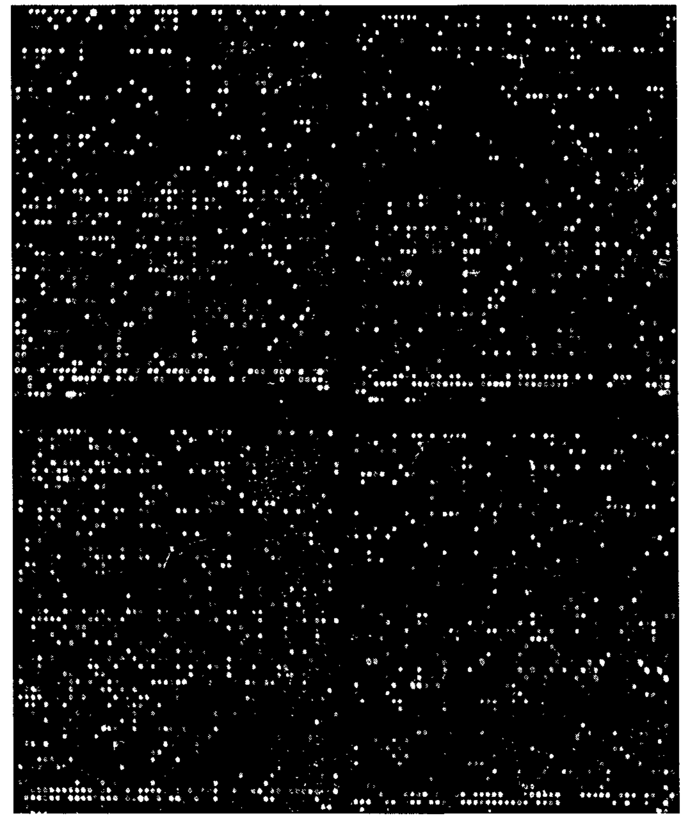
BWD Program Overview

Advanced Diagnostics

DARPA Advanced Diagnostics for BWD

Goals:

- Detect exposure/infection by any biological threat agent, and differentiate from other significant pathogens
  - in the body/clinical samples
  - in real-time
  - before symptoms appear



- Monitor the effectiveness of therapy

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The Need for Advanced Diagnostics

- During conflicts, 75% of casualties are disease non-battle injury
- Infections by different biological warfare agents may begin with the same flu-like symptoms, but have very different outcomes
- Effective treatment requires correct early diagnosis and pathogen identification

Advanced Diagnostics for BWD

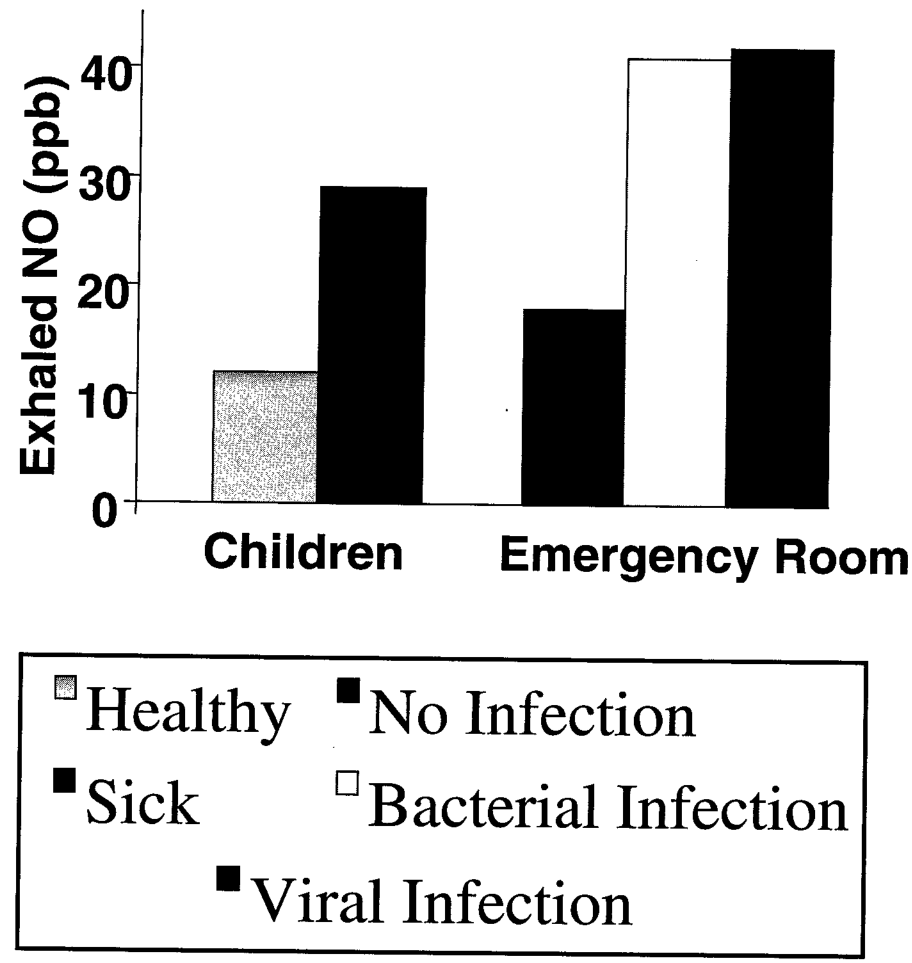
Approach:

- Leverage developments in commercial biotechnology (e.g., "PCR-on-a-chip")
- Develop new diagnostic technologies (e.g., rapid agent identification, cellular sentries)
- Identify new markers of diseases and develop into new diagnostic capabilities (e.g., exhaled NO detection)

“BW Breathalyzer”

Summary of Clinical Studies

- Exhaled NO levels are greater in symptomatic subjects
- NO increases early in infection, sometimes *before* self-reported symptoms change
- Prototype NO sensors developed



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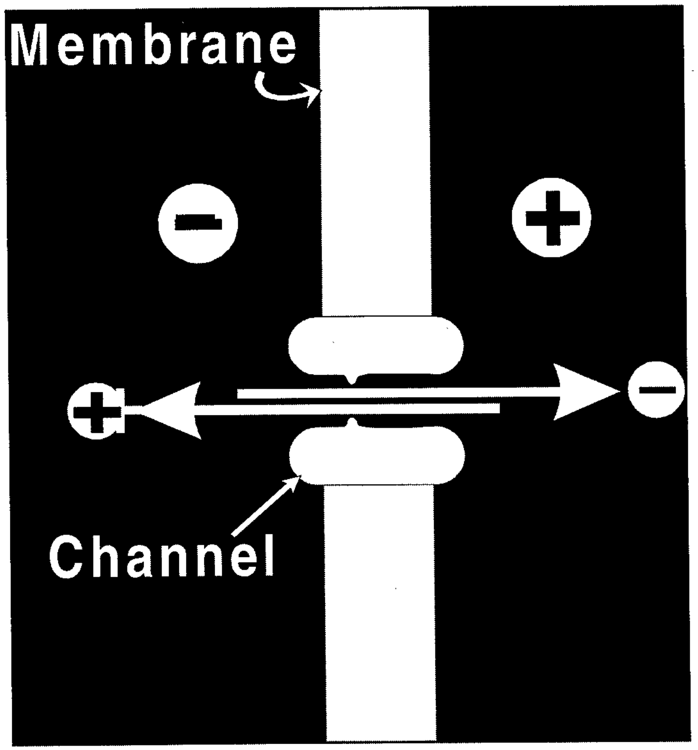
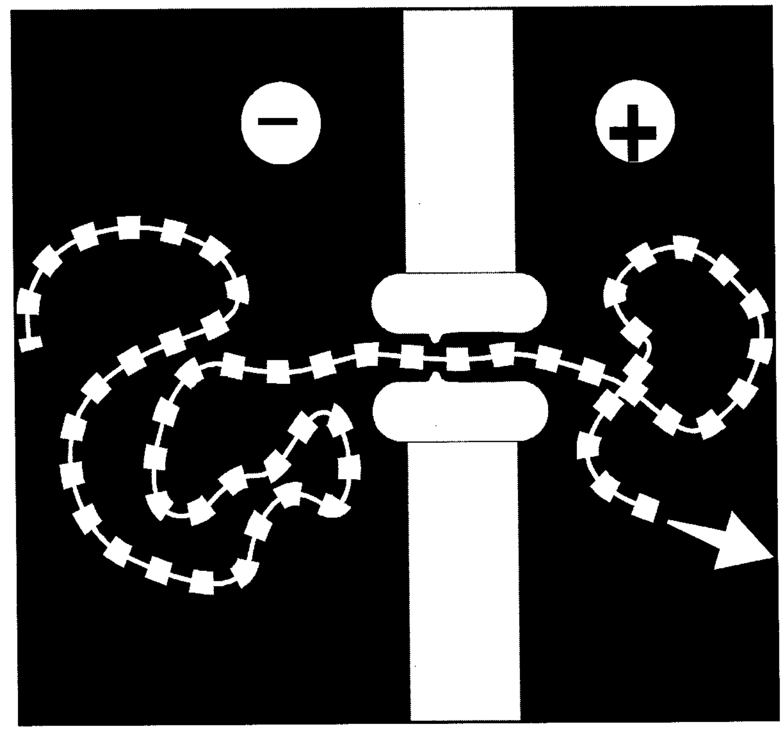
Single-Chain DNA Sequencing



Ions flow through an open channel



Reduction of ion flux reflects the properties of the nucleotide

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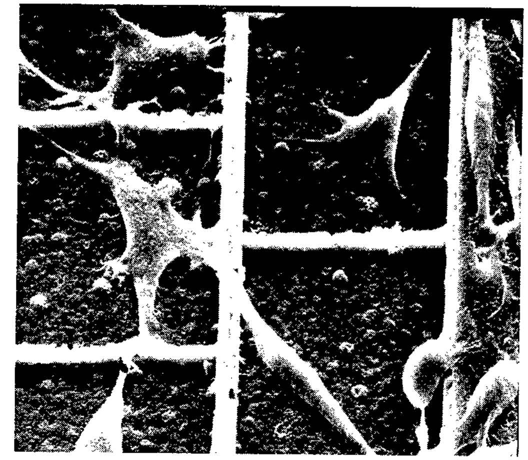
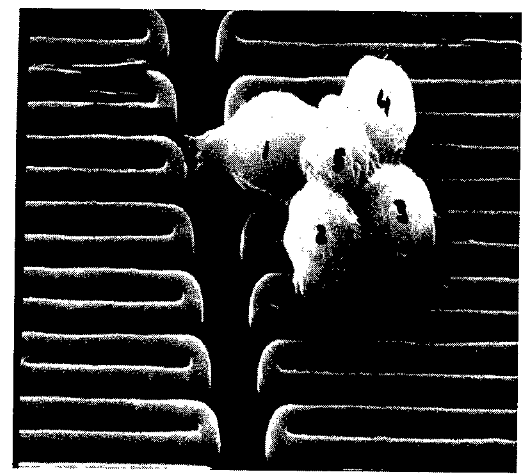
Tissue Based Biosensors

Goal:
Develop multifunctional physiological bioassay system(s) utilizing singular and multicellular arrays to provide early warning for chem/bio agents (toxins, nerve agents, bioregulators and other chemicals)





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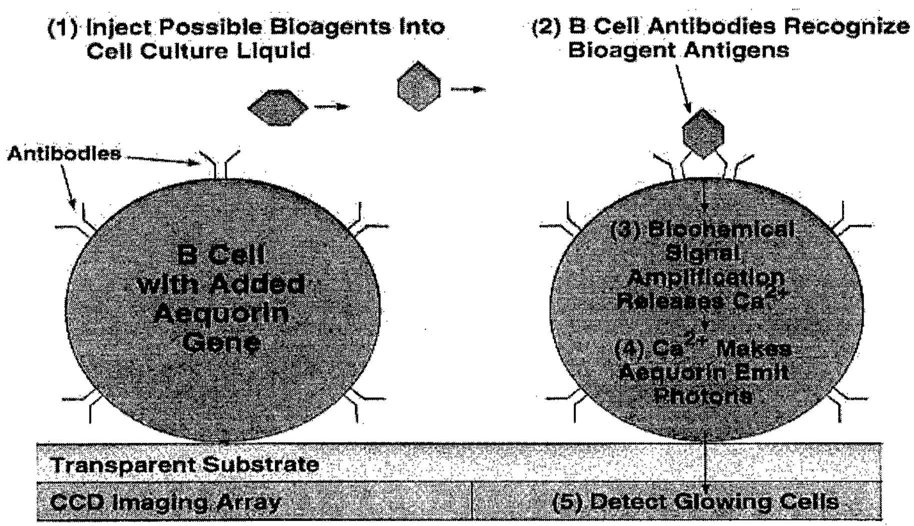
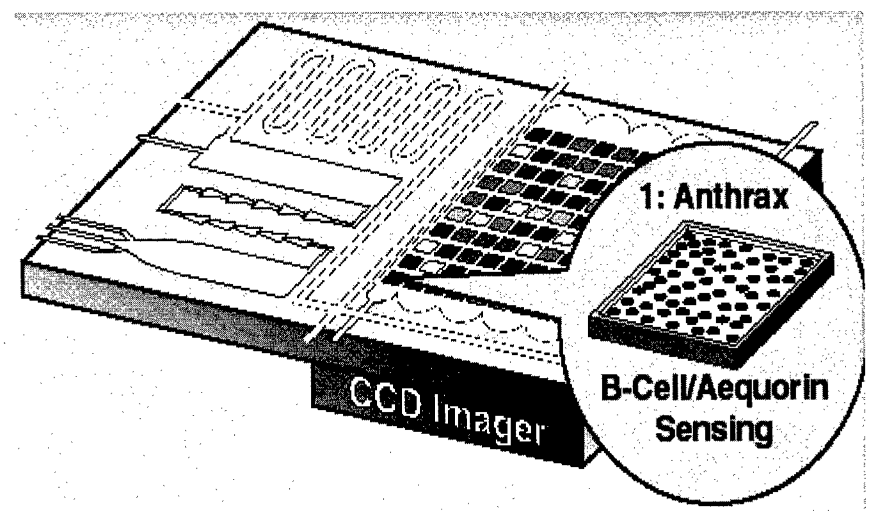
B-Cell Amplifier "CANARY"

Objective:
Use genetically modified cells as amplifiers for single particle detection of pathogens

Approach:
Engineer B-cells with a bio-luminescent protein to signal binding; integrate into a microfluidic chip





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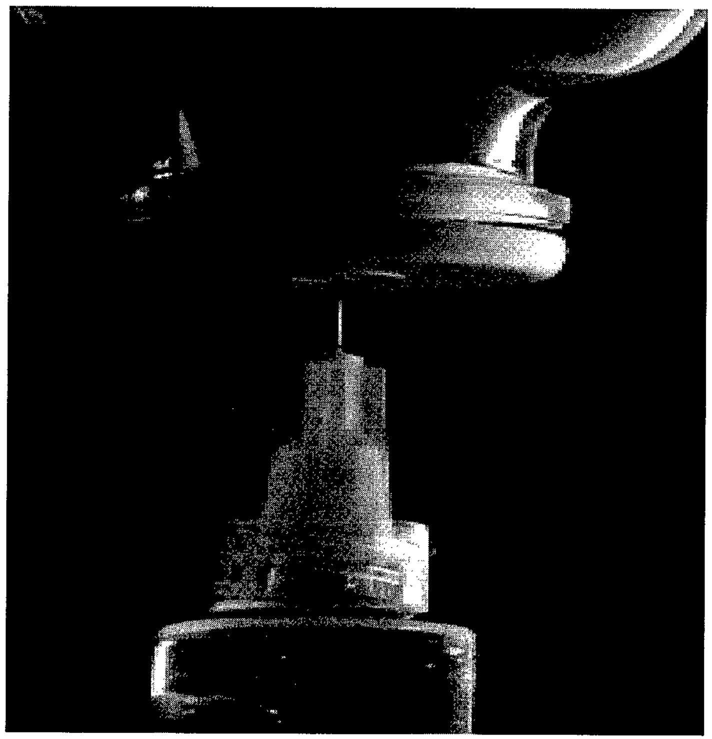
BWD Program Overview

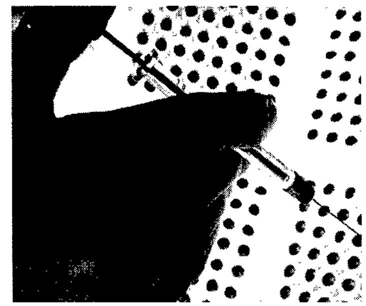


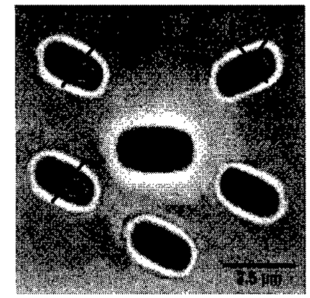
Medical Countermeasures

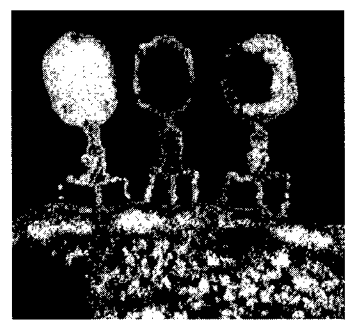
Medical Countermeasures

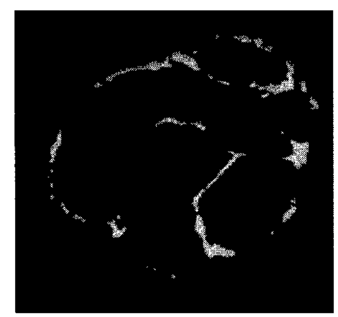
Program Goals:

- Defeat a pathogen's ability to enter the body and reach target tissues
- Target common mechanisms of pathogenesis and functions or structures shared by groups of pathogens
- Modulate the human biological response to pathogens


Rapid Immunizations


Anti-Bacterials


Anti-Virals


Anti-Toxins

DARPA Revolutionary Approaches to Vaccines

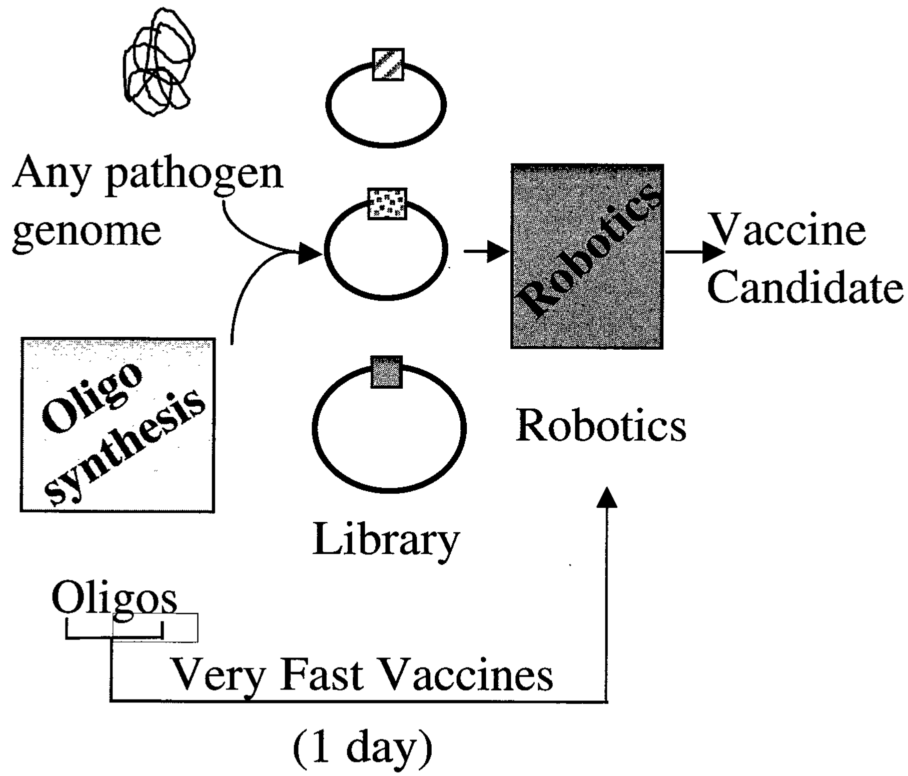
Fast acting
potent vaccines

Inducible
vaccine boosts

Systematic
vaccine production

Vaccines
in a day

High Throughput Vaccine Production



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Early Pathogen Genes

Why target genes turned on early?

- Likely to be important for the pathogen to establish infection
- Many of the most “generic” virulence steps (e.g., pathogen-host signaling mechanisms) are expressed early → identification of broadly applicable targets
- Want to treat patient as early as possible to minimize illness or death

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Early Pathogen Genes

Results:

- Identified over 200 genes **that are turned on early in the infection process and are shared by multiple pathogens**
- Identified 22 Two-Component Signal Transduction systems, critical to the pathogen because they sense the environment and ensure microbial adaptation
- Identifying and developing candidate therapeutics based on these functions

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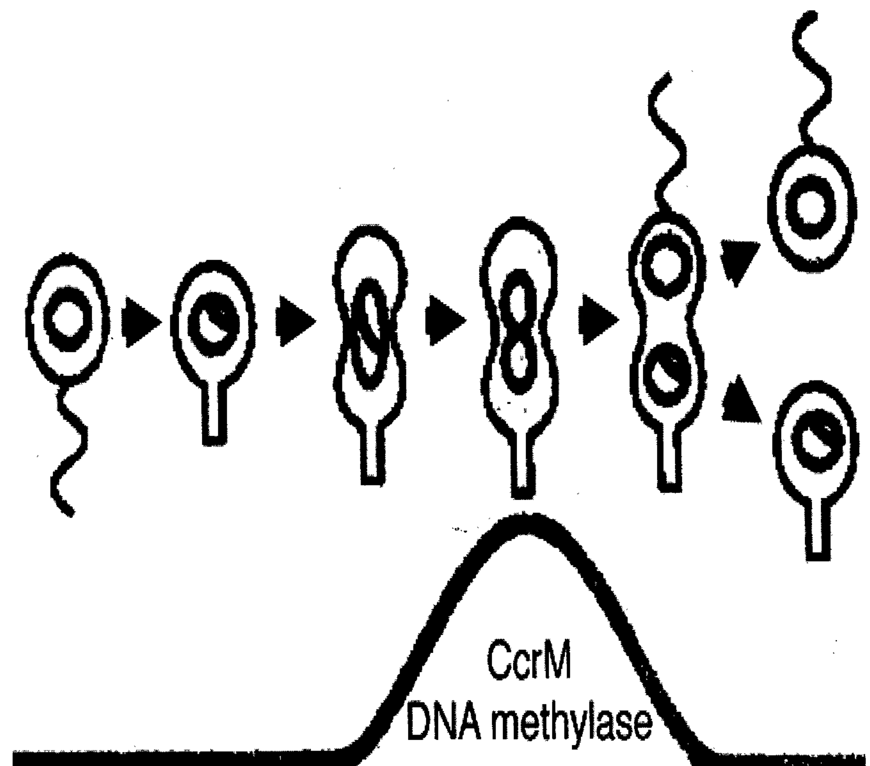
Enzymes Essential for Pathogen Survival

Target a newly discovered enzyme (CcrM) essential to bacterial pathogen survival

- First target Brucella abortus
- Identical target found in many other plant and animal pathogens
- Candidate compounds now being tested



Level and Timing of CcrM in Cell Cycle Critical to Bacterial Viability

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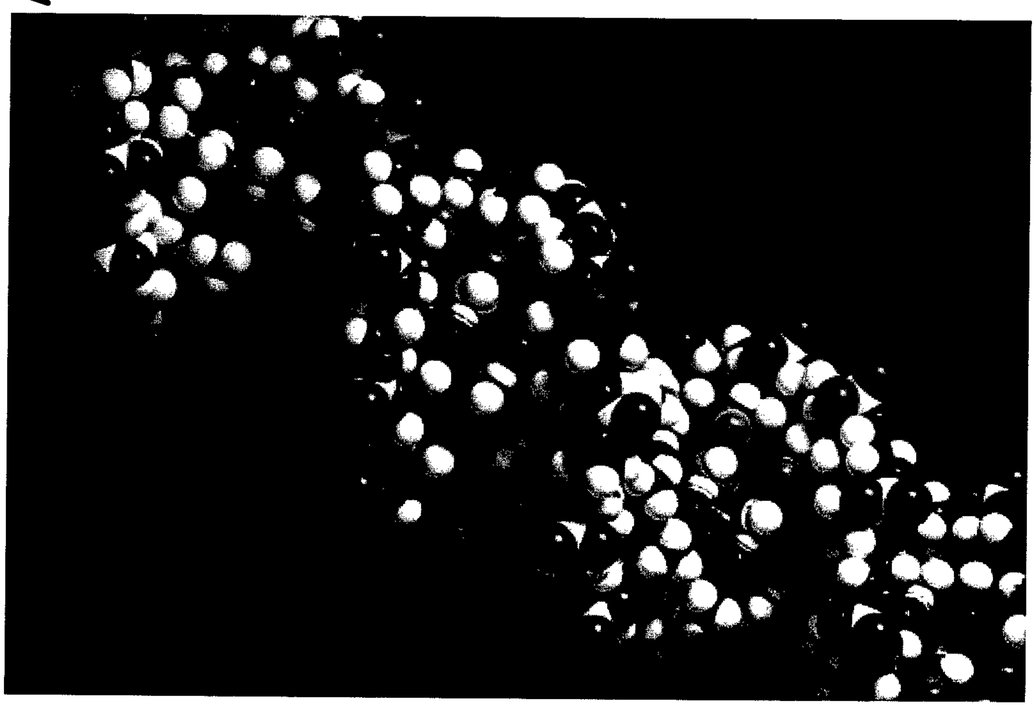
BWD Program Overview



Genomic Sequencing

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BWD Genomic Sequencing

Goals:

- Develop inventory of genes and proteins that distinguish pathogens from non-pathogens … look for general rules or patterns

- Identify pathogenic markers in any guise

- Provide superior molecular targets for identification and treatment

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BWD Genomic Sequencing

Approach:

- Sequence/annotate biological threat agents (viruses, bacteria and rickettsia) and their respective non-pathogenic "nearest neighbors"
- Identify genes and proteins whose expression is essential for pathogenesis
- Identify coordinately regulated genes/proteins and common regulatory elements

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BWD Website

http://www.darpa.mil/DSO/rd/Abmt/Bwd.html

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Controlled Biological and Biomimetic Systems

http://www.sysplan.com/cbs

Alan S. Rudolph Ph.D, MBA

"If one way be better than another, that you may be sure is Nature's way"

- Aristotle, fourth century B.C.E

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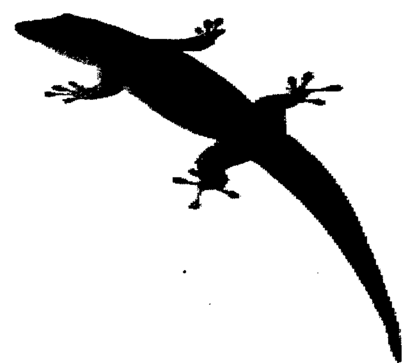
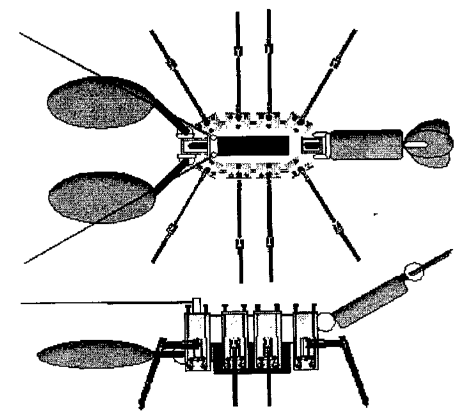
Controlled Biological and Biomimetic Systems

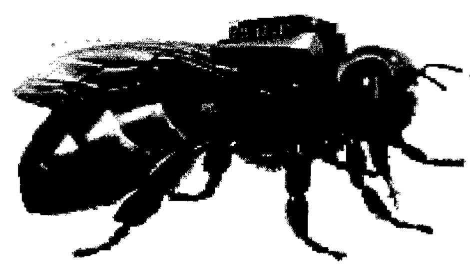
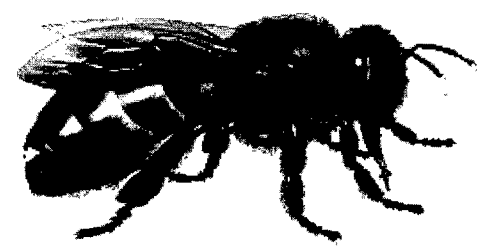




Understanding biological systems presents unique opportunities for developing new defense capabilities through mimicry, integration of living and non-living components, or direct use of complex biological systems

Controlled Biological and Biomimetic Systems

***GOAL:* Develop biological and biomimetic systems as mobile distributed sensors, sentinels, and delivery agents.**

Biomimetics	**Biohybrids**	**Biosystems**
		

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Biomimetics

Force Dynamics

walking, running, climbing, flying

Neural Control Architectures

object investigation, spatial navigation, target location

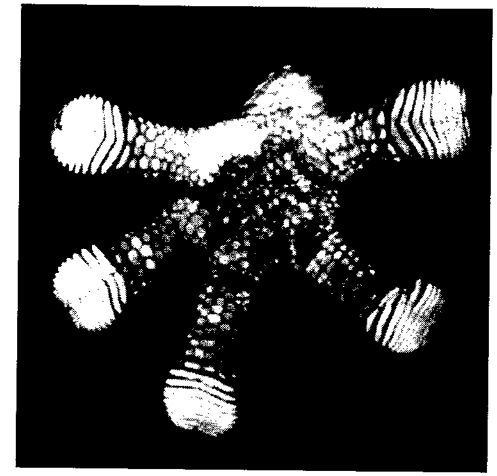
Sensorimotor Control

fusion of sensors and actuation, motivation to target

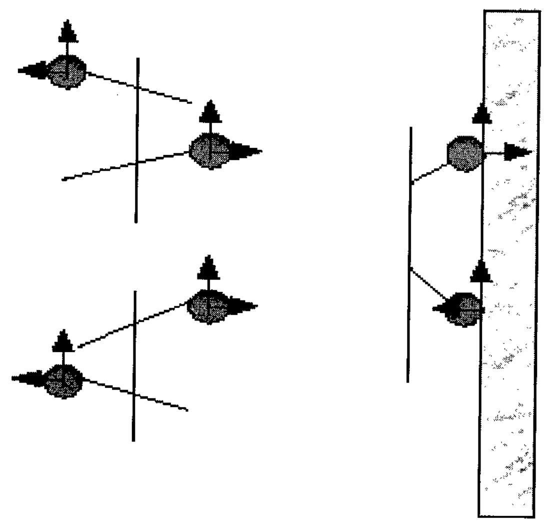
Force Dynamics of Climbing

Gecko climbs vertically at 1m/sec, attaches to multiple surfaces

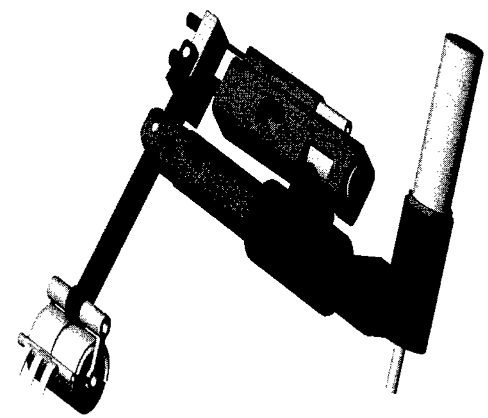
Feet are self-cleaning and use dry adhesion



Single-leg ground-reaction forces



Prototype leg designed, built and platform tested

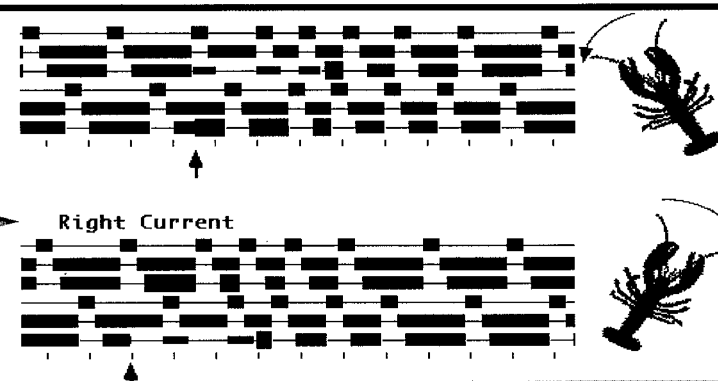


UC Berkeley/IS Robotics

DSO

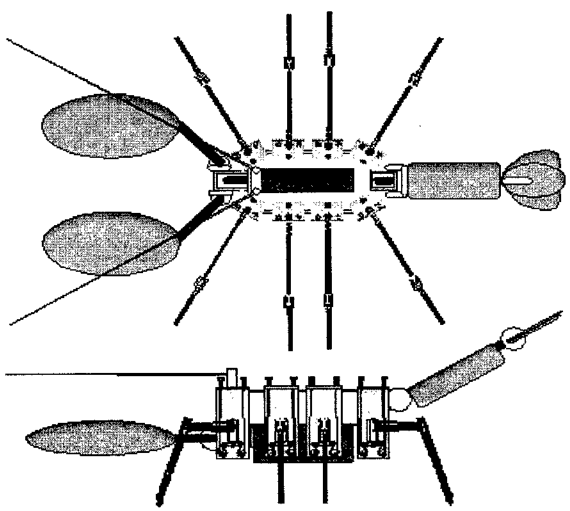
DARPA Neural Control Architectures

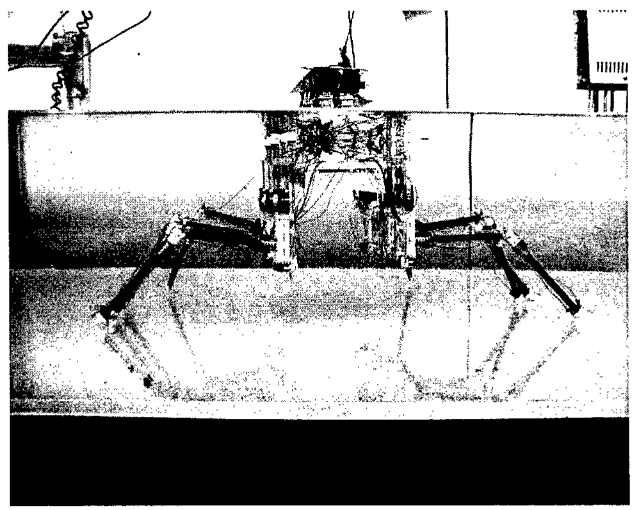
Kinematic analysis, muscle control signals

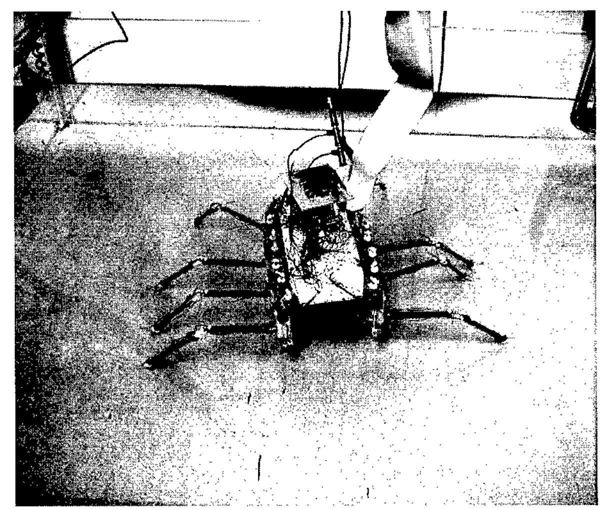


Behavioral action sequences

NEasternU/Massa Products







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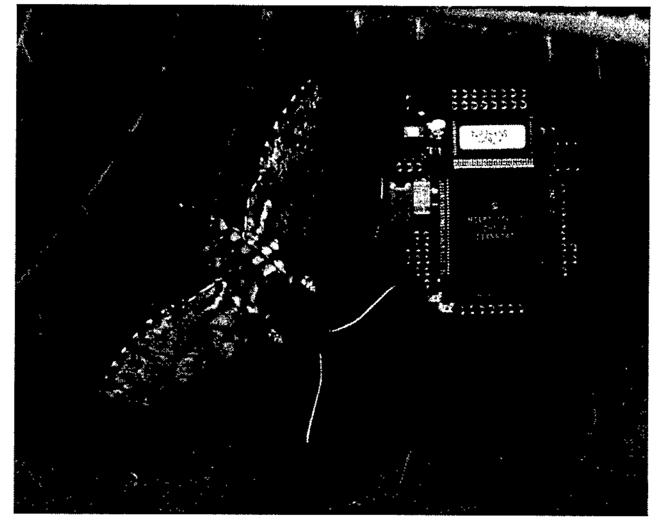
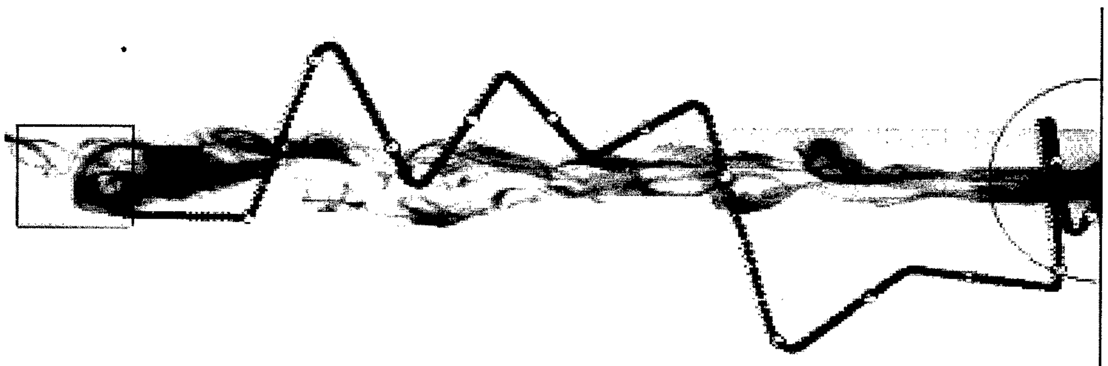
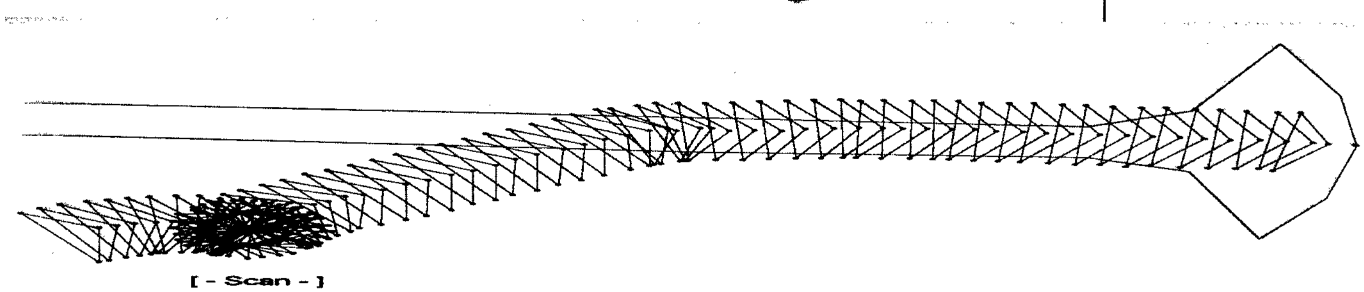
Sensorimotor Control and Navigation

Simulation model of odor-guided target location used by moths in following chemical plumes to a source.



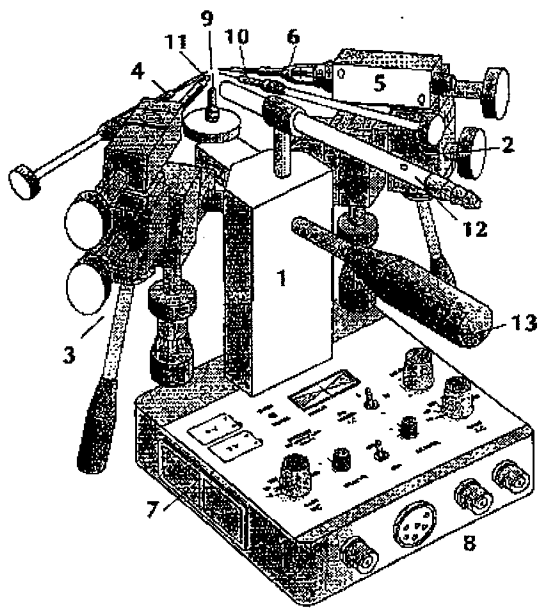
U Arizona/Tufts



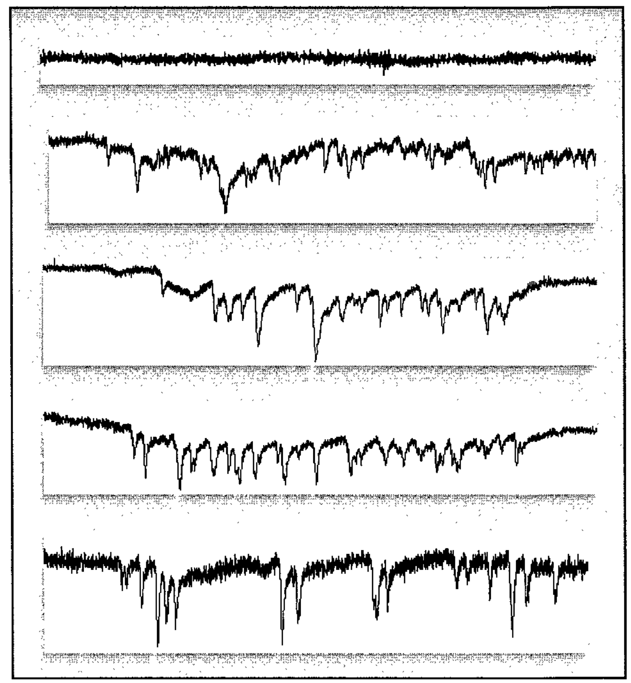


Biohybrid Systems

- *Explore the direct use of biological components*
- *Develop insect antennae to hand held device to detect odorant plume*

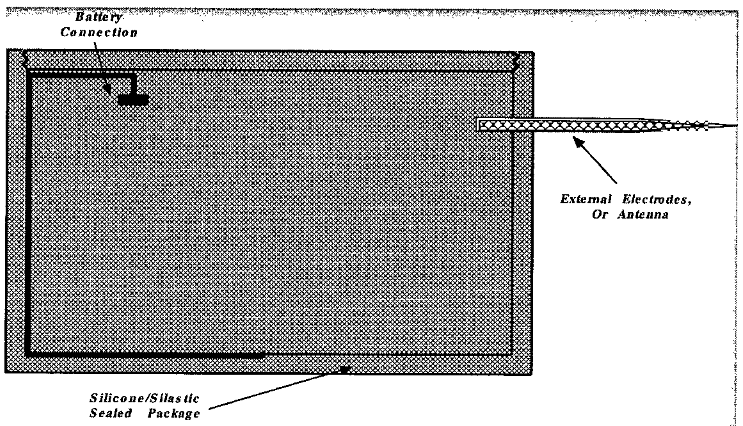


Iowa State

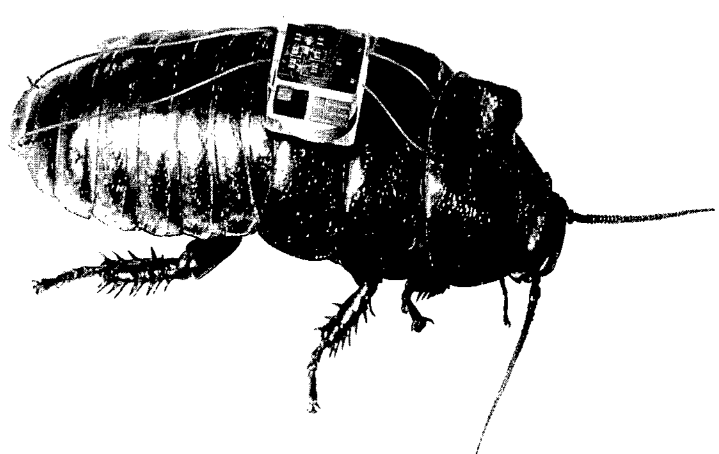


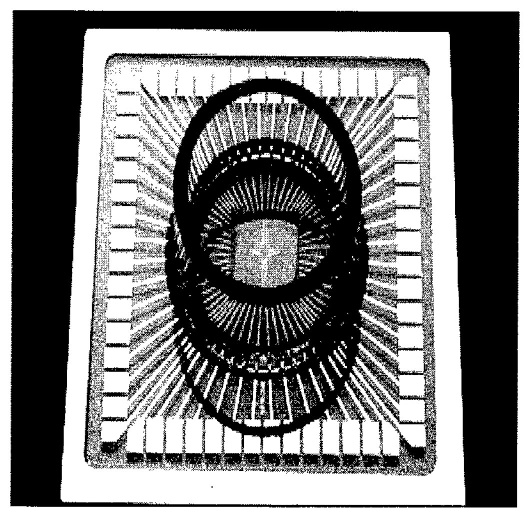
DARPA

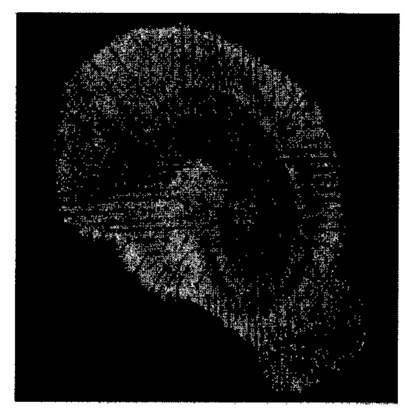
Biohybrid Systems



Design interfaces for real time recording and stimulation, two way communications







UMichigan/Duke/Plexon/USC

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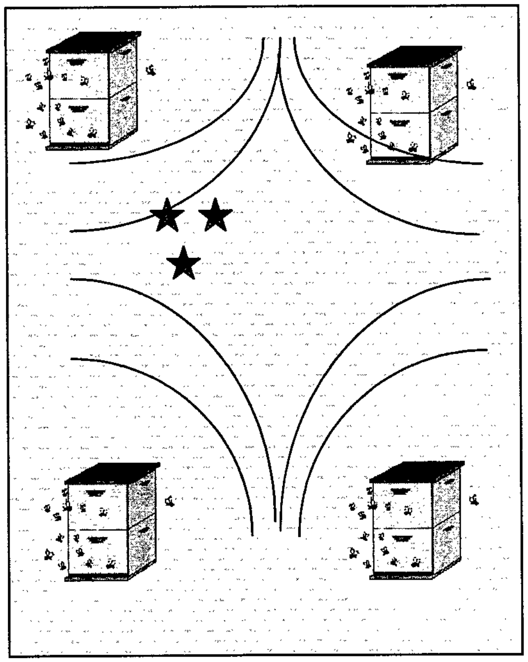
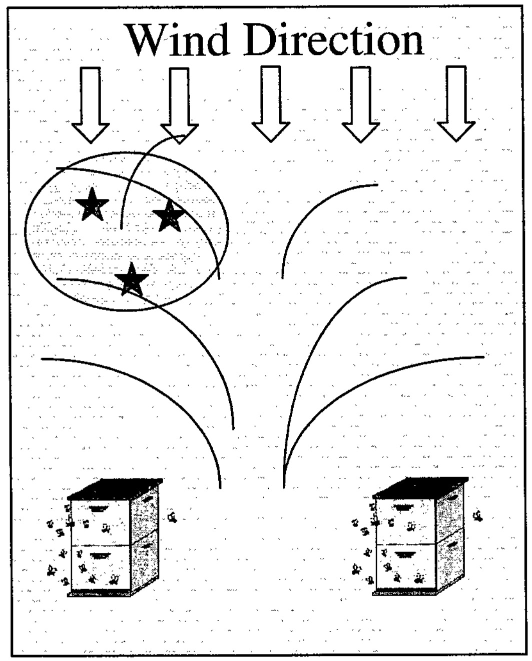
Target Identification Modes

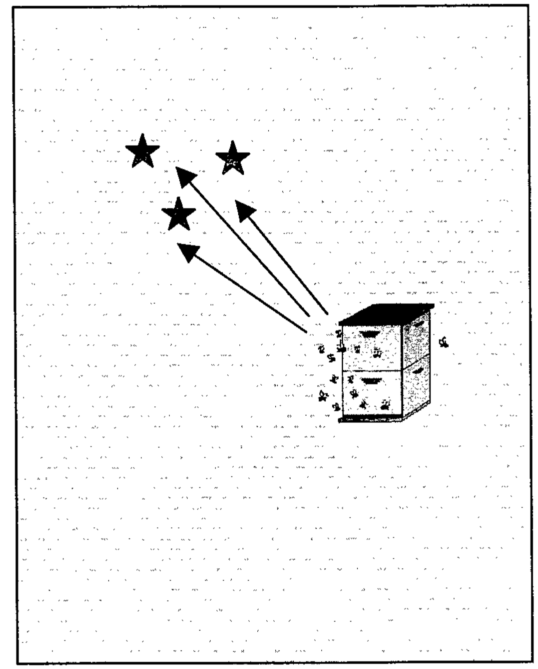
Undirected Sampling



Influenced Sampling



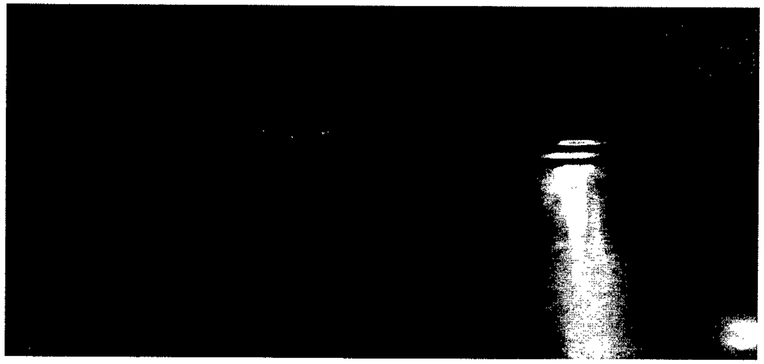
Directed Sampling



★ Target

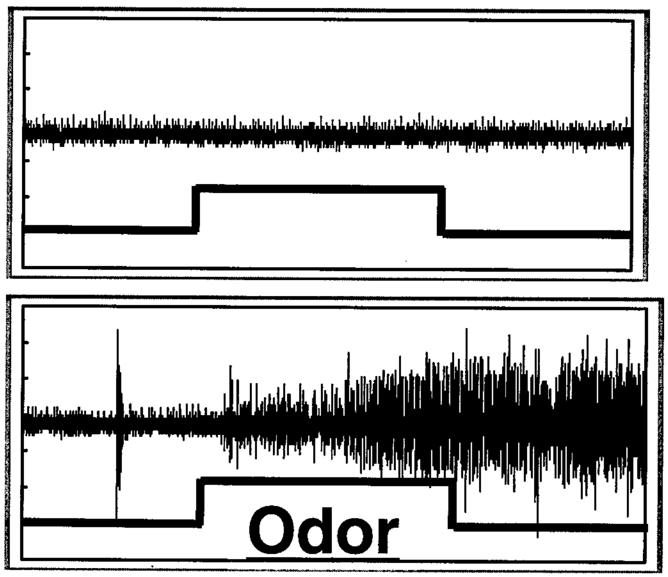
Attractant

Using Organisms for Target Location

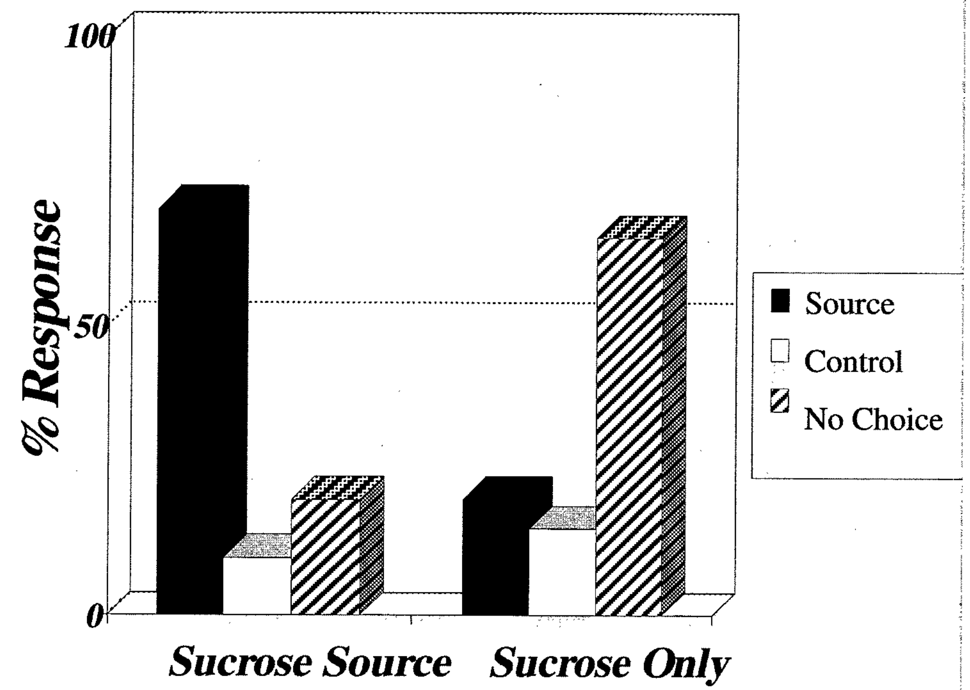


Physiological Response before and after training

Before



Train Organisms to UXO Compounds:2,4 DNT



Preflight Experience

USDA/Iowa State/ORNL/UArizona

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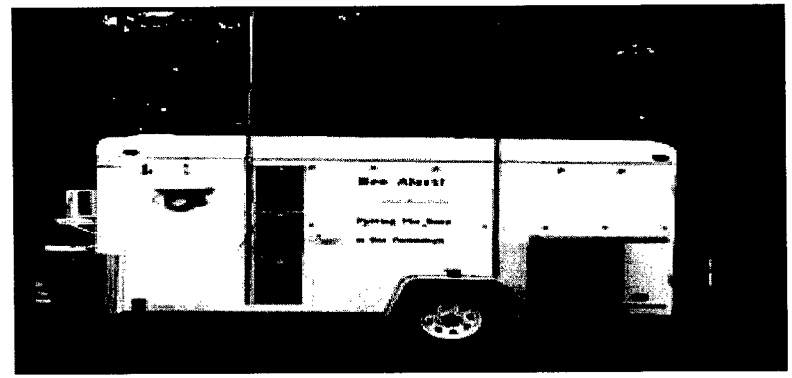
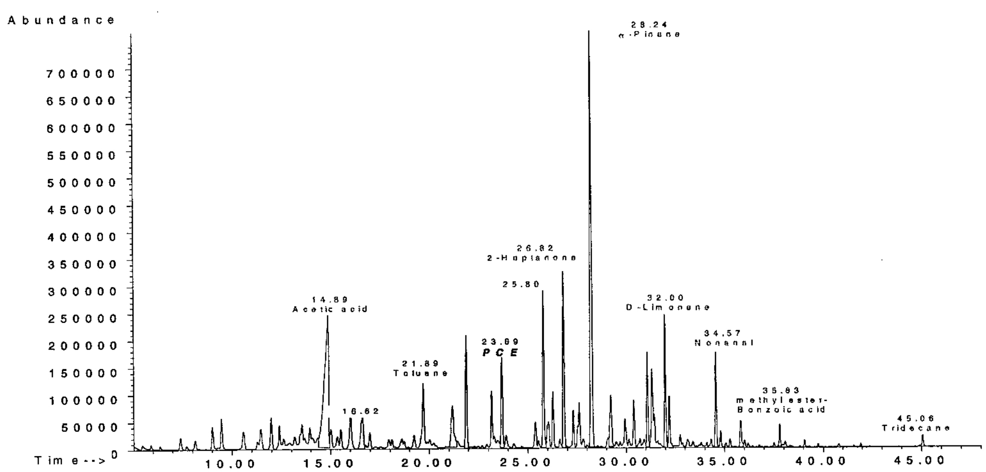
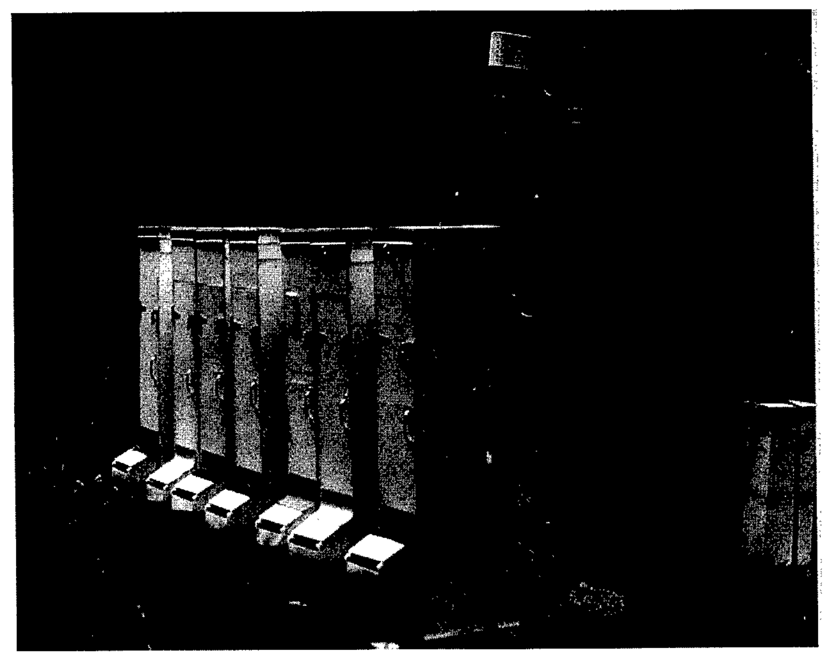
Engineering Bee Colonies

Use individual and social insect behavior and activity for environmental sampling and target location







U Montana/EPA/USDA/CEHR

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DARPA

Mission Applications

Biological Systems

- Animal Sentinels - ‘Sensor Web’ for situational awareness, locate suspected targets (CBW depots or plants)

Hybrid Biosystems

- Living machines -use as sensor or navigational devices

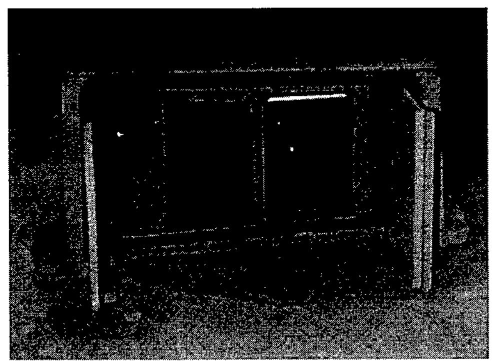
Biomimetics

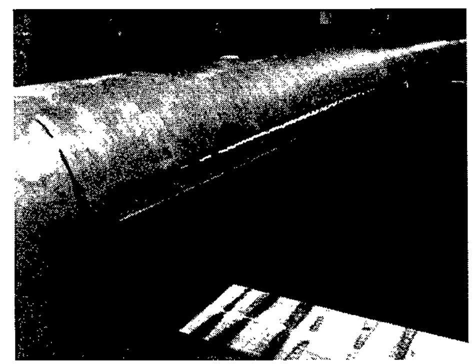
- Fault tolerant locomotion and sensing
- Armament neutralization

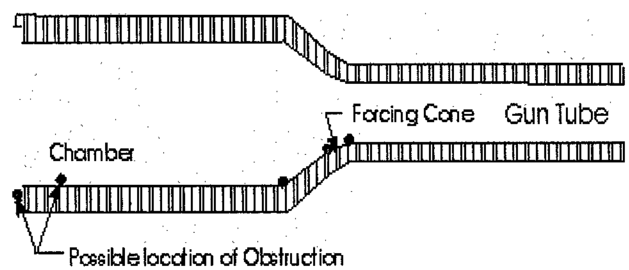
SPIKER - Non-lethal Armament Neutralization

- Explore the feasibility of introducing defects into armaments that would result in non-lethal failure

- Implement asymmetrical controlled biological or biomimetic systems to deliver payloads and execute defects







USA-TACOM

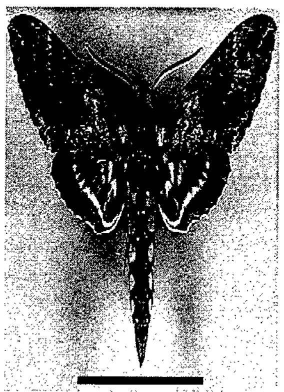
Controlled Biological and Biomimetic Systems

Enhancing Defense Capabilities through Life Sciences

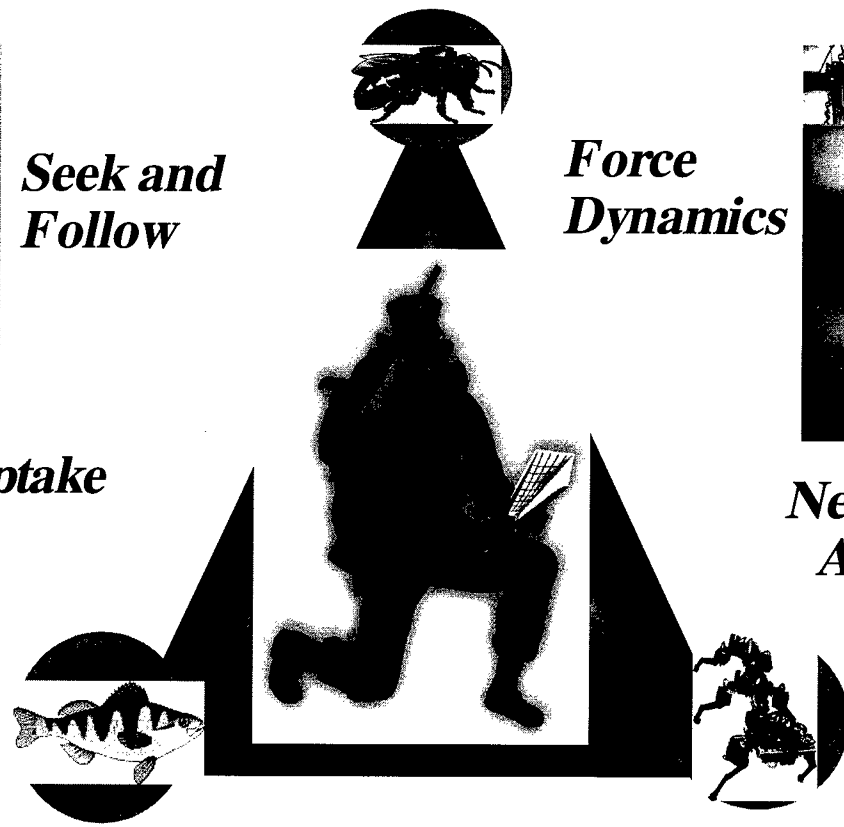
Signals and Alarms

Sensorimotor Navigation

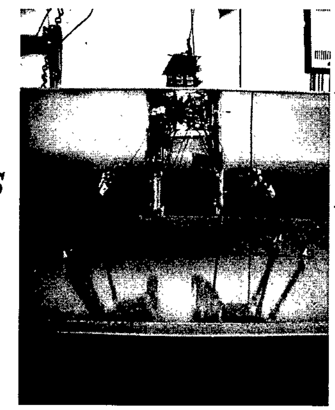
Chemical Analysis and Reporting



Seek and Follow



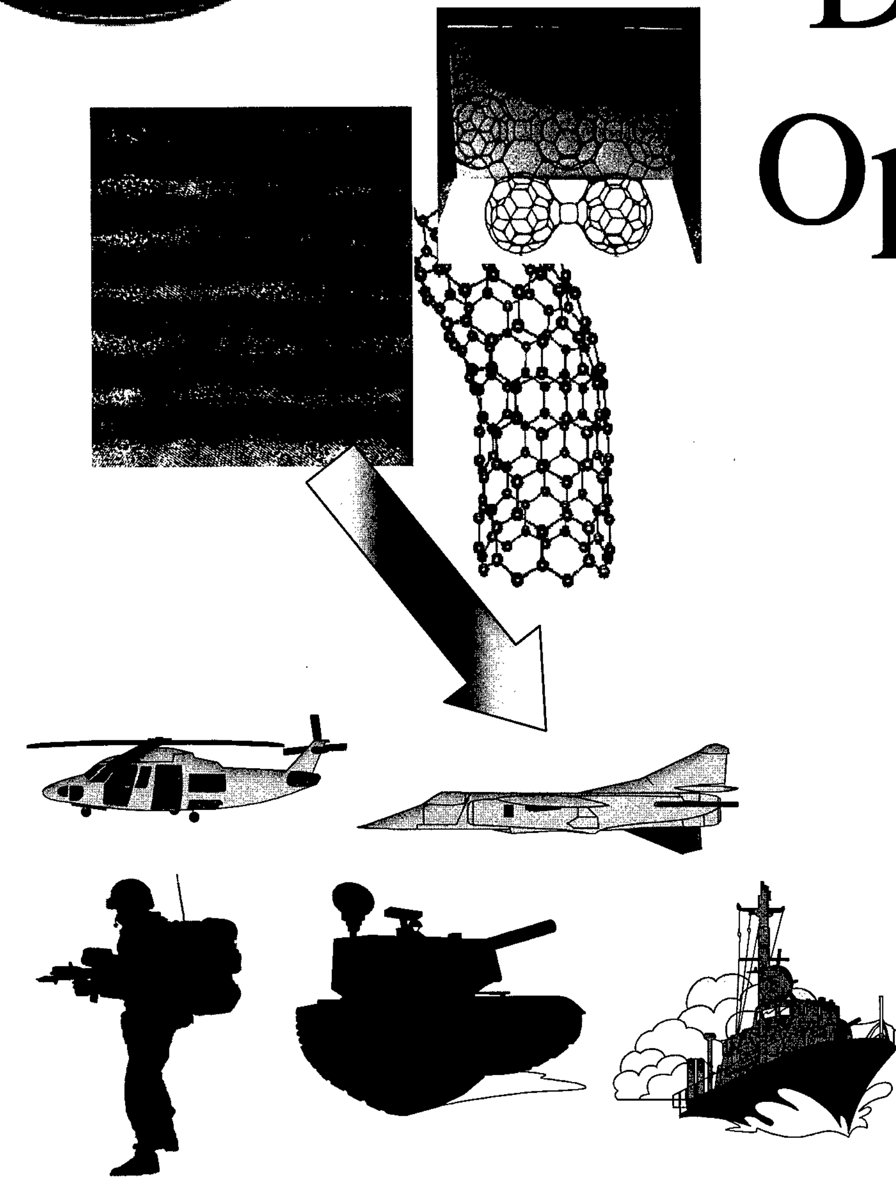
Force Dynamics



Fault Tolerant Locomotion

Transport and Uptake

Neural Control Architecture

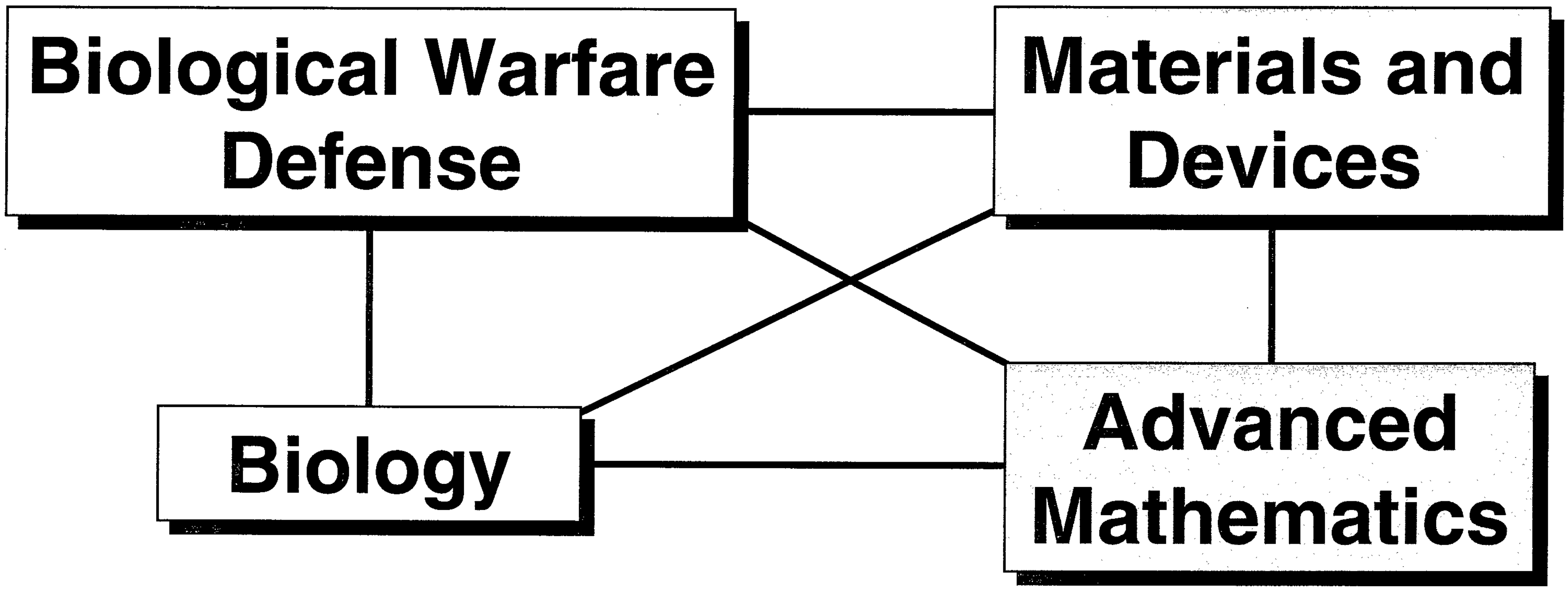


Directions and Opportunities in DARPA's Materials Program

Steven G. Wax

DSO

DSO Program Synergism



Materials and Devices

- Smart Materials and Demonstrations
  - Garcia, Coblenz, Wax
- Structural Materials and Components
  - Wax, Coblenz, Christodoulou, Lyons
- Functional Materials and Devices
  - Wolf, Warren, Browning
- Mesoscopic Machines
  - Warren, Wax
- Power Generation and Storage
  - Nowak, Wax

DARPA

Materials Synergies

- Biology
  - Biomimetic Materials
    - Rudolph, Wax, Christodoulou
- Defense Applications of Advanced Mathematics
  - Virtual Integrated Prototyping
    - Healy, Wolf

DARPA

Program Philosophy

New Concepts in Materials

- Rapid Design and Prototyping
- Micro/nanostructure Control
- Computational Materials Science
- Combinatorial Synthesis
- Biomimetics
- Multi-functionality

Emerging Defense Needs

- Force Projection, Mobility
- Littoral Operations
- Information Driven Warfare
- Aging Platforms
- Small Units, Urban Warfare
- Unmanned Systems
- Nuclear/Chem/Bio Threat

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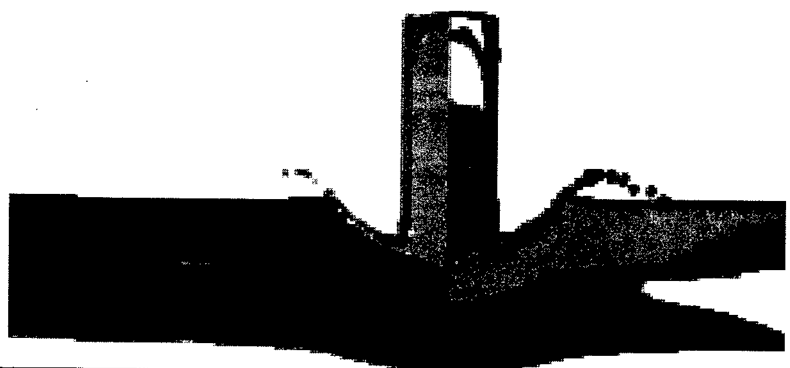
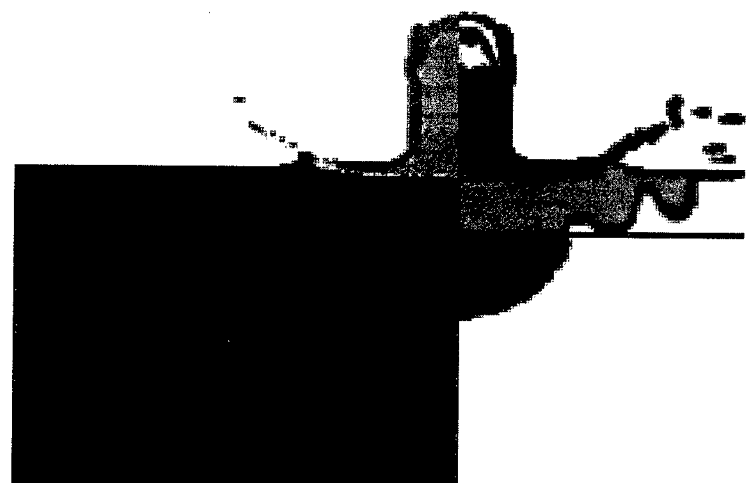
Ultra-lightweight Armor Program

Establish New Designs for Body Armor Material Systems

- **Target: 3.5 lbs/ft^2 (7.62 mm AP) vs. Current 6.5 lbs/ft^2**
- **Exploiting New Mechanisms**
- **Understanding/Predicting Behavior (Model→Test)**



5.08-mm B_4C/6.60-mm Al



5.08-mm B4C/ Semi-inf. RHA

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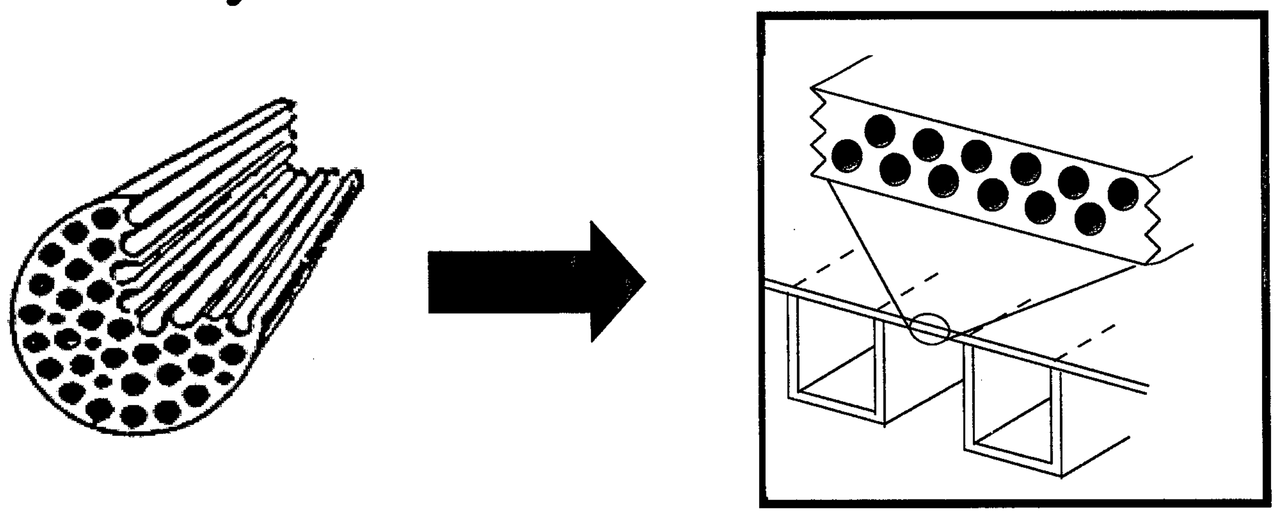
Multi-Functional Materials and Structures

- Designed Compositional and Morphological Arrangements
  - Perform Multiple Functions Simultaneously (Often Inspired by Nature)
- New Paradigm for Structure Design
  - Significant Impact on DoD Systems Performance, Survivability and Maintenance



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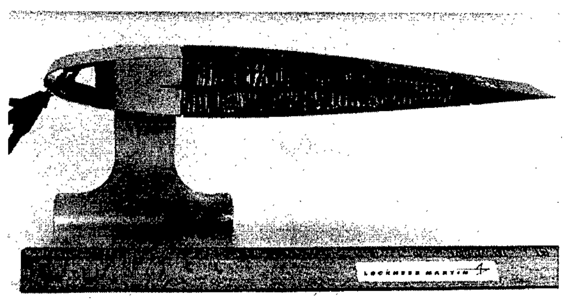
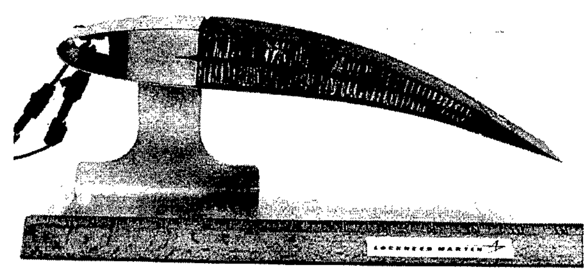
Smart Materials and Structures

Material Development ⟺ **High Authority Actuators** ⟺ **Demonstrations**

- Single Crystal Perovskites
- Electroactive Polymers
- Shape Memory Alloys
- Piezoelectrics
- Electrostrictors
- Magnetostrictors

- Helicopter
- Fixed Wing Aircraft
- Submarines/ Torpedo





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DARPA

Electroactive Polymers

Tailorable, Responsive Electroactive Properties

Polymer Chemistry

Structural Properties of Polymers

Actuation and Sensing

Electro-Optical Response

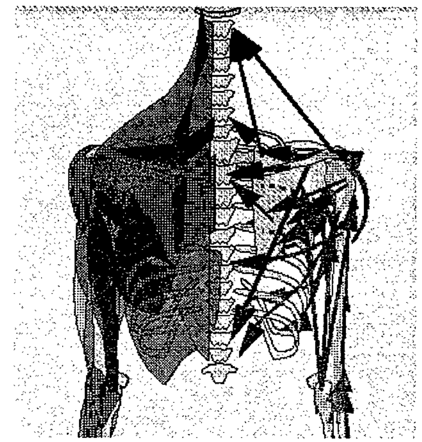
Artificial Muscles and Smart Skins
Acoustic (Sonar)
Biomimetic Devices

Analog Processing
Flexible Displays
Flexible Electronics

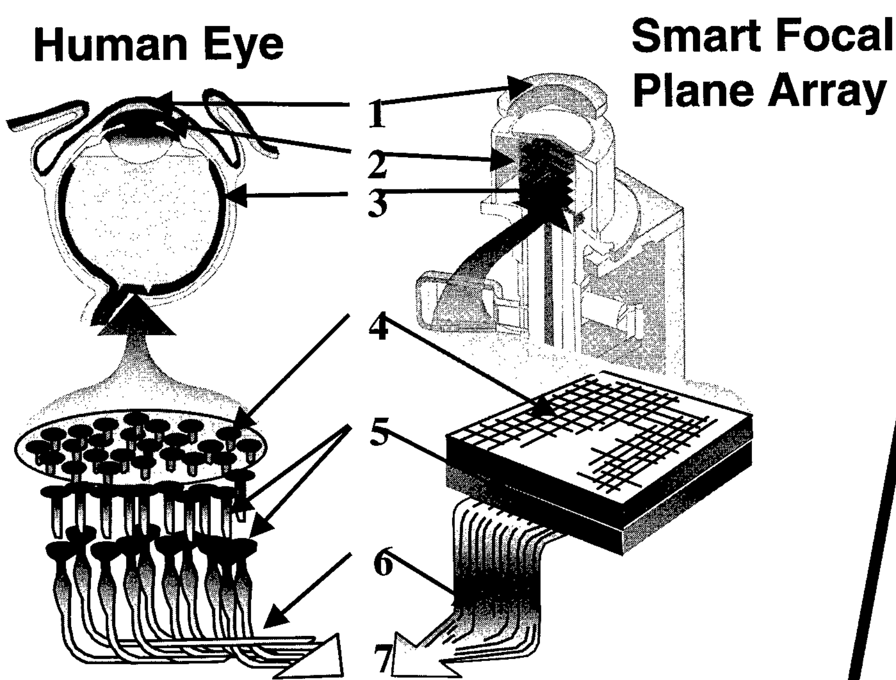
Electroactive Polymers are "Intrinsically" Smart Materials

Electroactive Polymers
Actuation

- Promise
  - Bio-Inspired Actuation (Mammalian Muscle)
  - Microactuation
- Advantages:
  - Compactness
  - Low Overhead
  - Intrinsic Sensor Capability
  - Localize Actuation Control

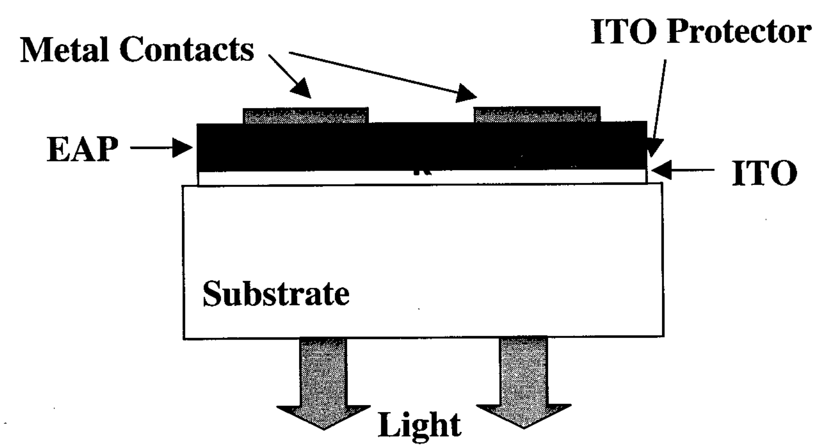


Electroactive Polymers
Applications



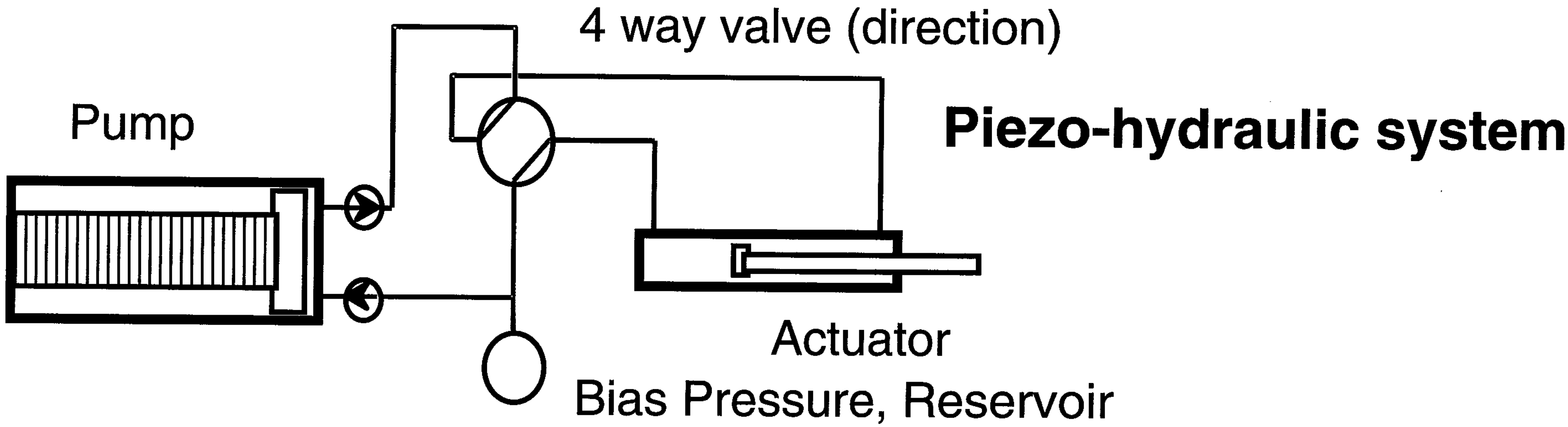
Artificial Retina
(Uniax, Ratheon)

Green Light Emitting Polymer (Dow Chemical)



Compact Hybrid Actuation

- System Level, Concurrent Design
  - Mechanical & Electrical Transmissions
  - Power Electronics
  - Controllers
  - Fatigue, Reliability & Durability



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POWER SYSTEMS MATERIALS & PROCESSES

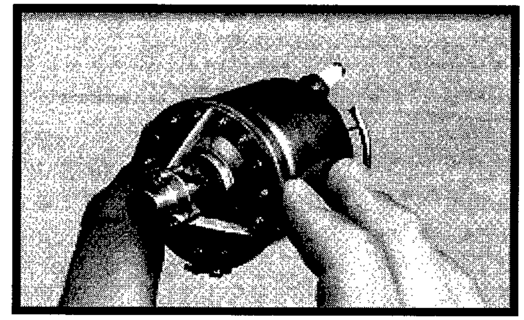
POWER SOURCE DEVELOPMENT DEPENDS ON NEW MATERIALS

- Electrodes, Electrolytes
- Catalysts
- Emitters
- Filters
- MEMs
- Seals, Interconnects
- Superconductors
- Thermoelectrics
- Photovoltaics
- Permanent Magnets

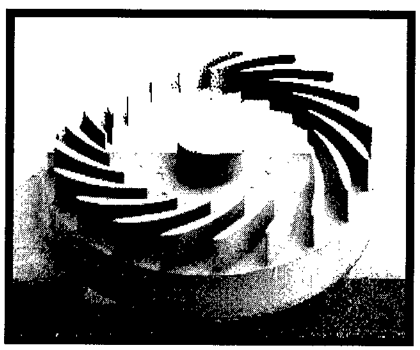
- Batteries
- Fuel Cells
- Capacitors
- TPV, Solar
- Microturbines
- Heat Engines
- Motors
- Energy Harvesting

World's Smallest Turbine Engines

- Current: Gas Turbine Driven, Electric Power Generator
  - Quiet………………...Field Deployable
  - Powerful…………..1 kW Class/1.3 shp
  - Portable…………..Less Than 1 kg
  - Miniature………....The Size of a Soda Can
  - Efficient…………... 3 hr on a Liter of Heavy Fuel
  - Robust……………Multi-Fuel/Low Maintenance



M-Dot, Inc



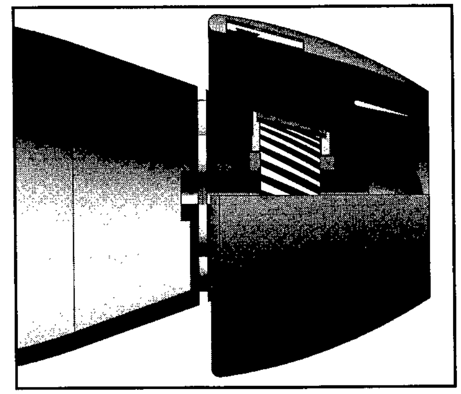
MIT

- Future: >2 kW-hr/kg 

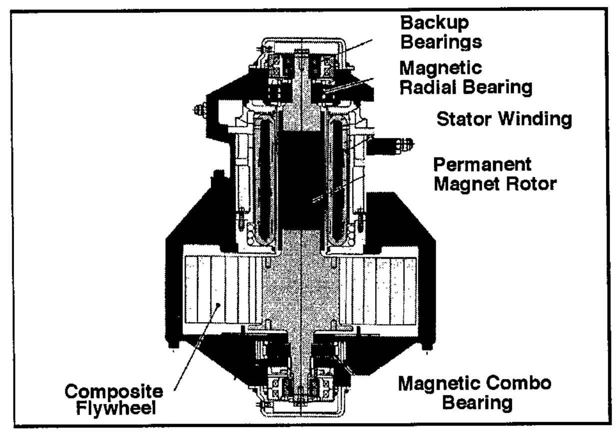
Advanced Magnets for Power

- Magnetic Alloys and Compounds for Advanced Power Systems
  - High Energy Products (100 MGOe)
  - High Temperature Operation (>250 C)
  - Mechanical Strength

YBM Magnex, Inc. Has Already Shown a 20% Improvement in Energy Product With a New FE-B-H Alloy



Integrated Motor Propulsor



Flywheel for Combat Hybrid Power Systems (CHPS)

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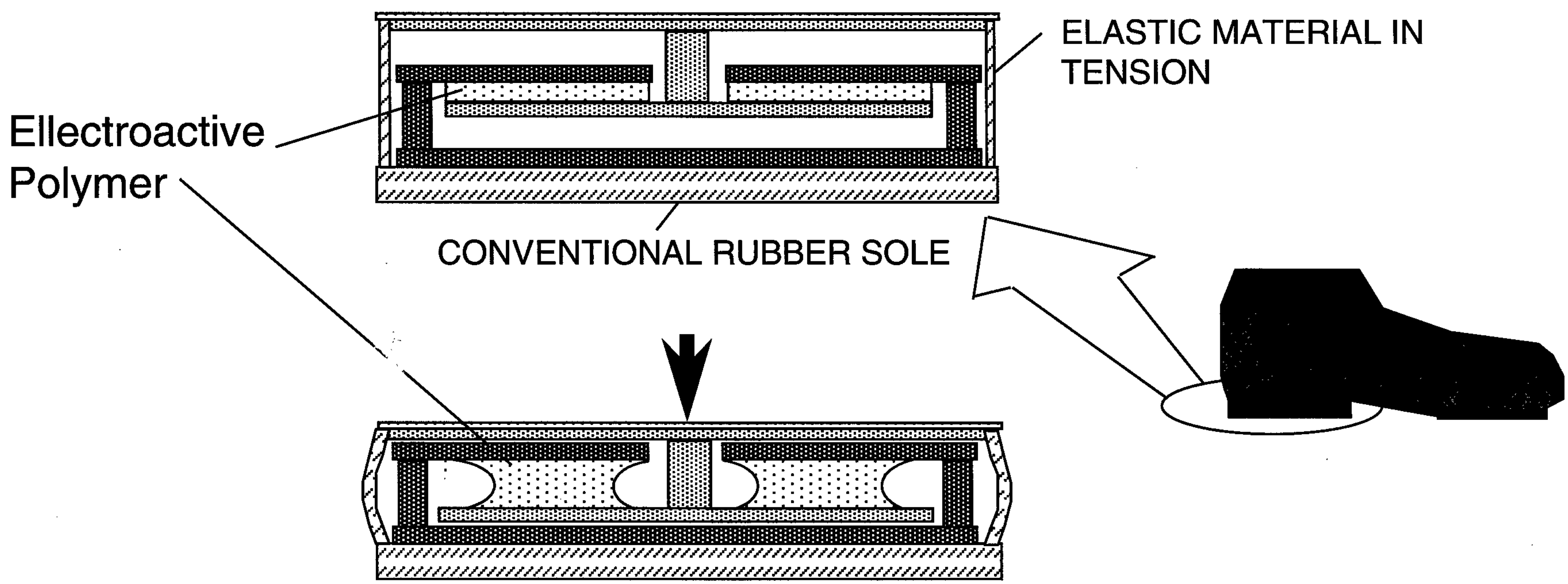
ENERGY HARVESTING
(mW'S - W'S)

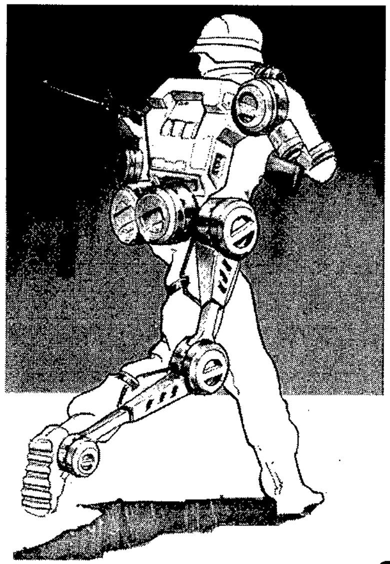
- Photovoltaics
  - Thin-film Manufacturing
- Mechanical
  - Ocean Currents, Heel Strike
- Thermal
  - Ground-air, Ocean-air Interfaces
- Chemical Gradients
  - Ocean Sediments
- Natural Fuels
  - Cellulose, Plant Sugars, Blood Sugar

Heel-strike Generator

- Recover up to Several Watts of Power During Normal Walking Without Burdening the Wearer
- Power Is Used to Charge Batteries or Directly on Boot for Specialized Functions



Mechanical Augmentation of Human Capabilities



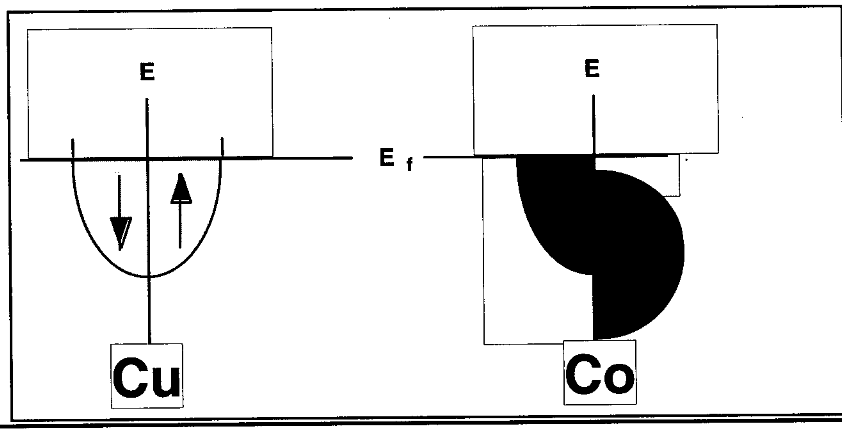
- Move at the Speed of Battle in All Terrains
- Enhanced Load Carrying Capability
- Efficient Power Usage, Easy Re-fueling

Technology Issues

- Smart, Efficient Actuators
- Non-battery Power Sources, Power Distribution
- Sensors, Feedback, Control
- Reliability and Cost

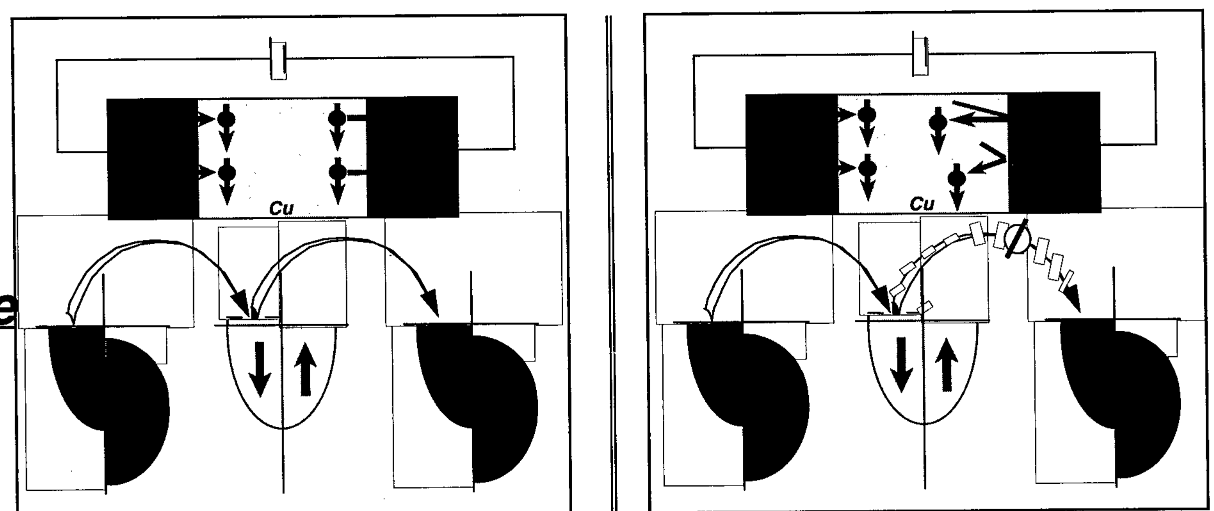
Spintronics

A New Approach to Electronics!



Metallic Energy States

Spin Magnetoresistance



Low Resistance ***High Resistance***

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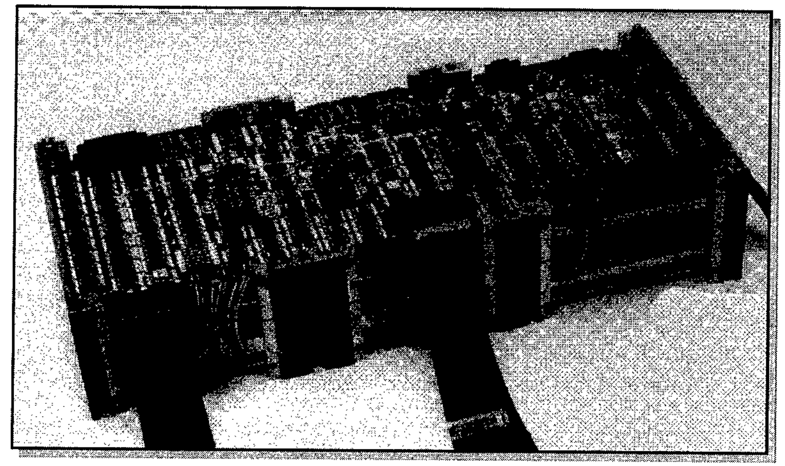
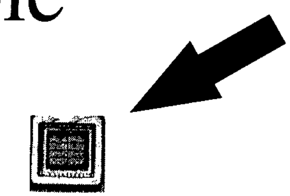
Spintronics for Magnetic Memory

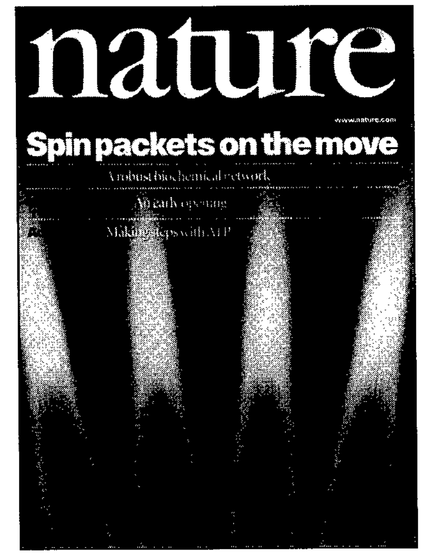
- Non-Volatile, Radiation Hard Memory for Space, Missile and Avionics Applications
  - Speed of SRAM (<3 ns)
  - Density of Dram (4 Gbit)
  - Low Power (0.1 - 0.01x)
  - Low Cost (0.1x)
  - Infinitely Cyclable





Coherent Spins in Semiconductors

- Discoveries:
  - Room Temperature, Optically Induced, Very Long Lived Quantum Coherent Spin State in Semiconductors (UCSB, 1997-1999)
  - Ferromagnetism in Semiconducting GaMnAs (Sendai, Japan 1998)



- Potential Applications
  - Quantum Computing in Conventional Semiconductors
  - Very Fast, Very Dense, Low Power Memory and Logic
  - Magnetic Sensors With SQUID Like Performance
  - Optical Encoders and Decoders

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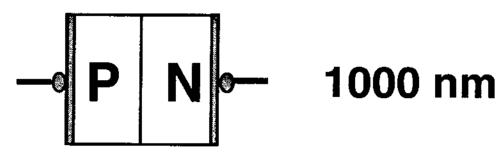
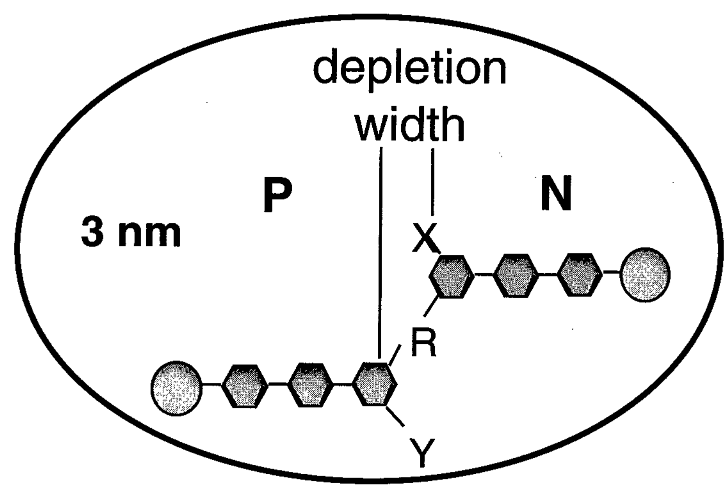
Molecular Electronics
(Moletronics)

- Self-assembled Miniaturized Computational Engine Using Molecular Electronics
- Attributes
  - 3-D
  - High Density
  - Room Temperature
  - Low-power
  - Compact
  - Self-assembled
  - Requires Fault-tolerance





DSO

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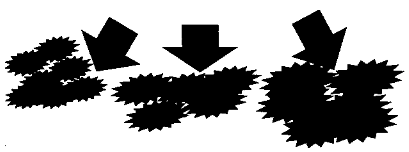
Nanotechnology

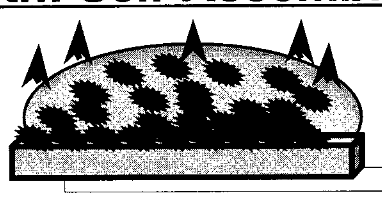
"Small is Different"

Ferromagnets => Superparamagnets
Ferroelectrics => Superparaelectrics
Semiconductors => Quantum Dots
Metals => Coulomb Islands

Size Selective Processing

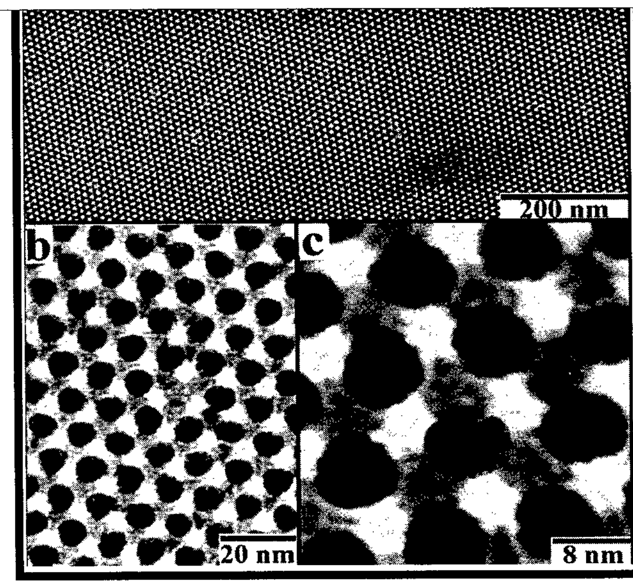


Film Growth: Self-Assembly



Nanocrystal Superlattice

Superlattice of 8 nm Cobalt Nanocrystals



Murray
IBM

DSO

DARPA Multi-scale Design and Integration

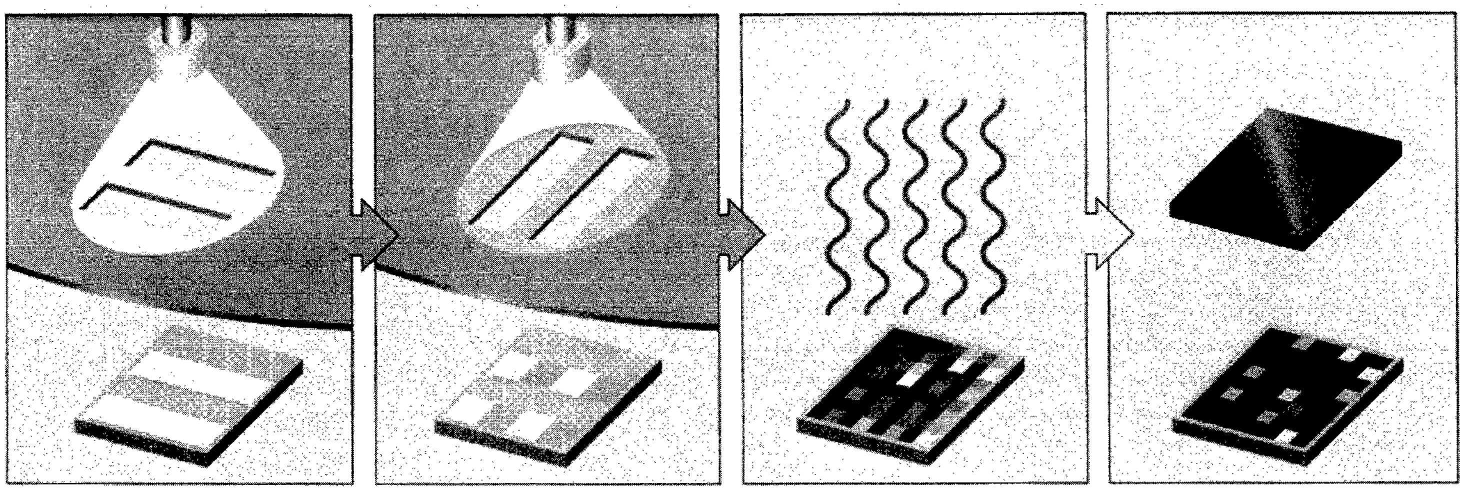
- For Multi-scale (mm to nm) Devices
  - Conventional Subsystems, Mesomachines, MEMS, and Evolving Nano-scaled Technologies
  - e.g., Hybrid Power Management Systems
- Functional Integration To Maximize Efficiency
  - Power, Actuation, Fluids, Electronics, Structure, etc.

Combinatorial Synthesis

Deposit large library of inorganic compounds

Process (T, P, t, etc.)

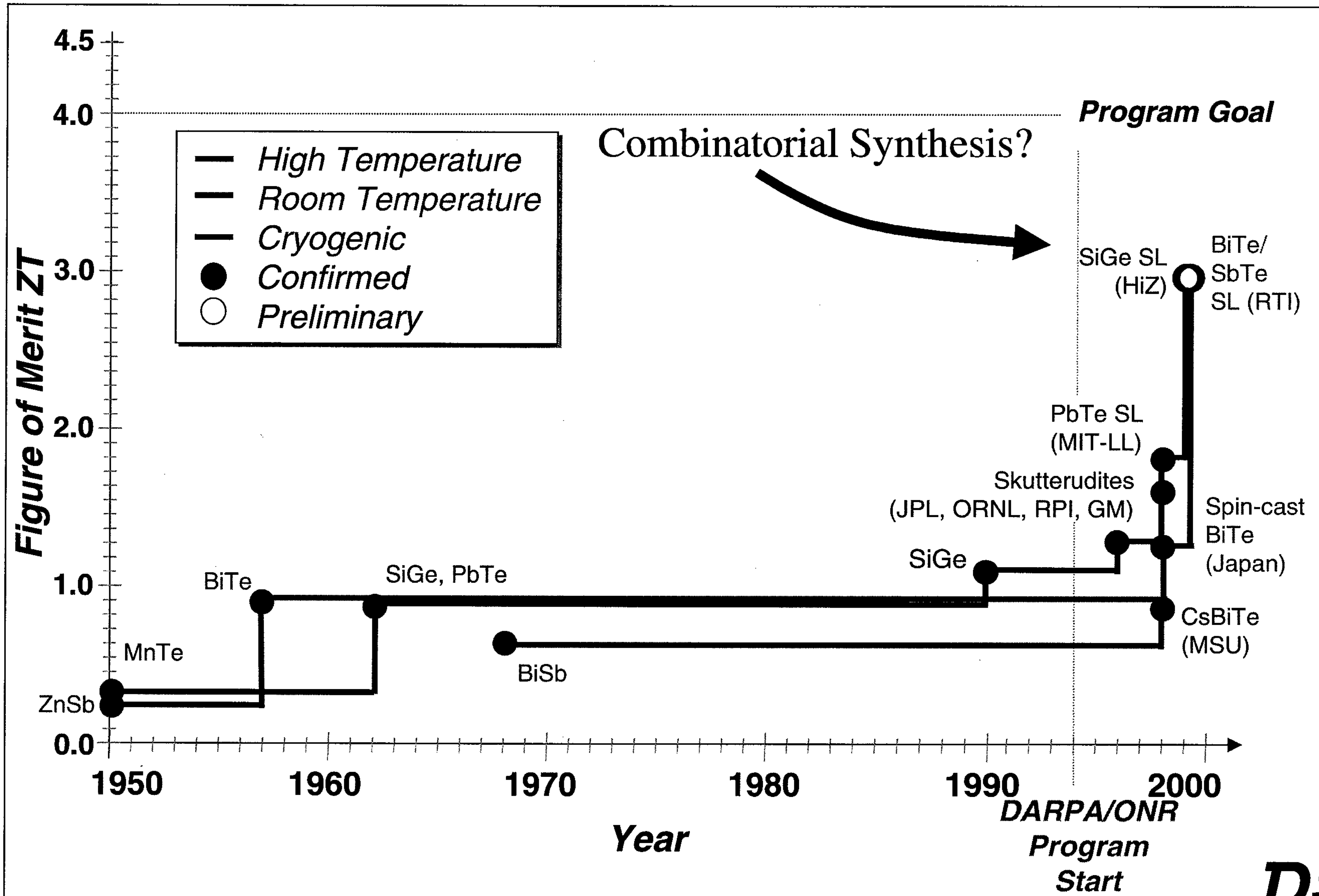
Measure properties



- Accelerate the Discovery of New Materials
- Determine Optimum Processes and Synthesis
- Rapid Diagnostics Is The Key!

DSO

Thermoelectrics



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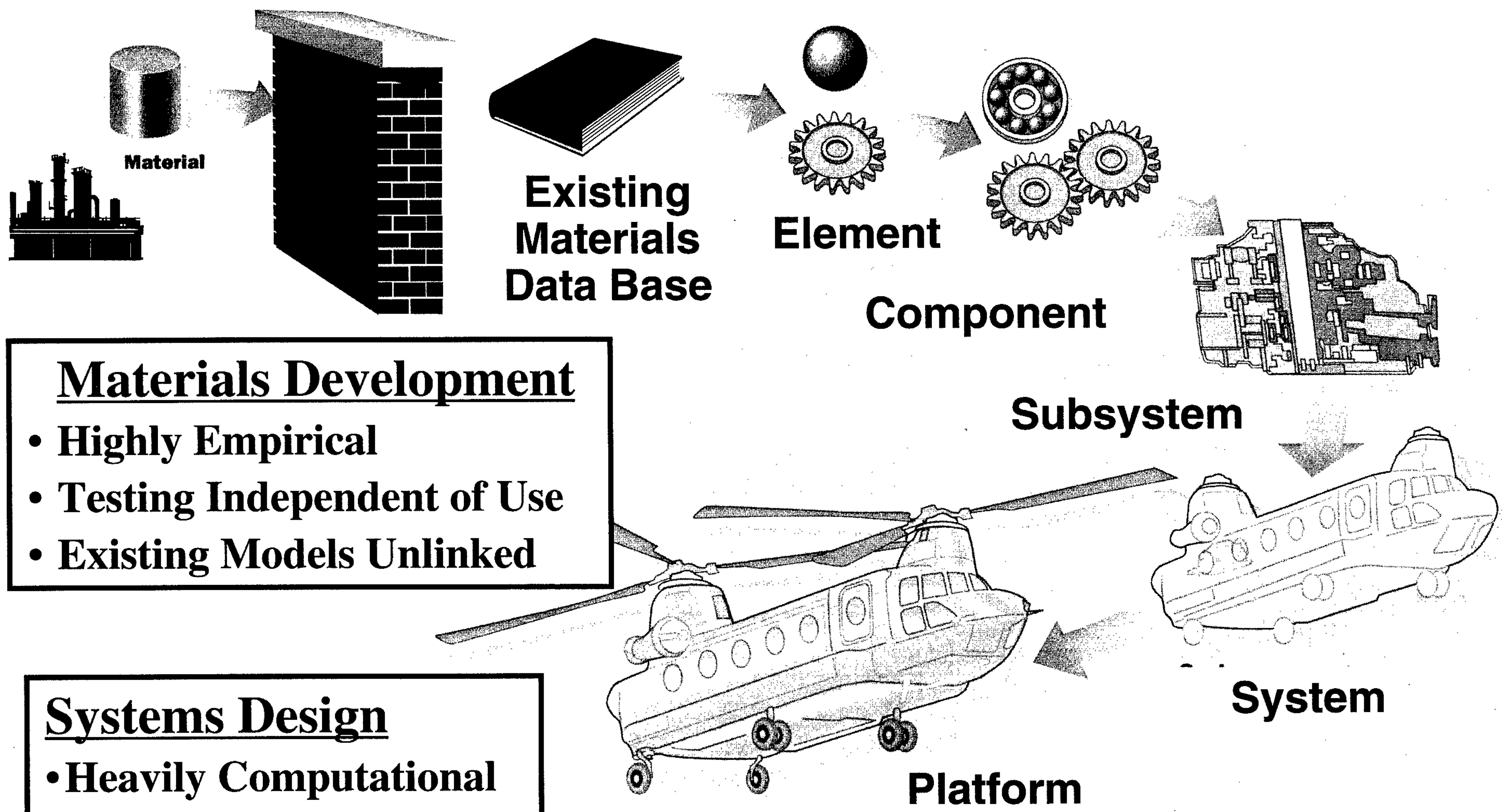
The Dilemma in Materials Development!



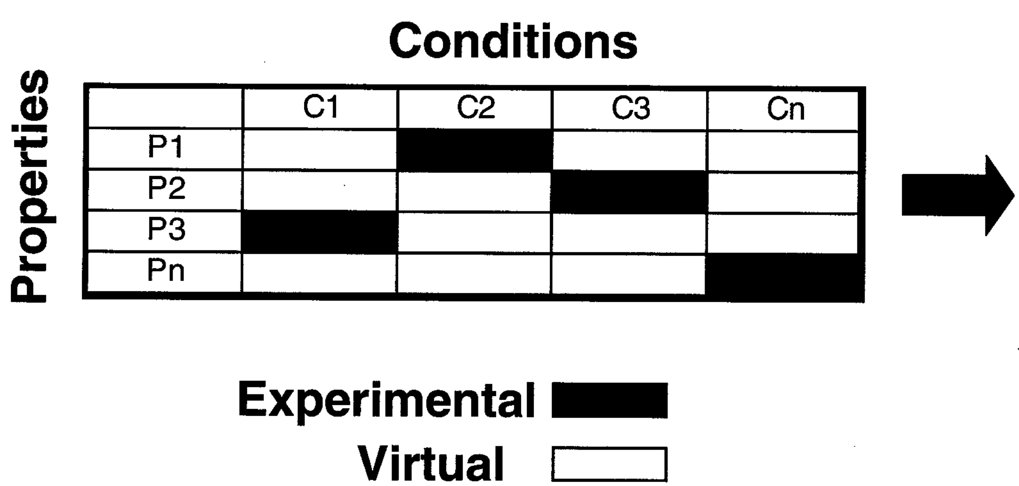
Materials Development
- Highly Empirical
- Testing Independent of Use
- Existing Models Unlinked

Systems Design
- Heavily Computational
- Well Established Testing Protocols

DSO

Accelerated Insertion

- **Modeling and Experiment in the Optimal Construction of a "Database" That Satisfies Designers Needs**



Reliable Manufacturing Process

Predictable Properties

Predictable Life-Cycle Costs

Maximum, Reliable Performance

Growing/Emerging Opportunties

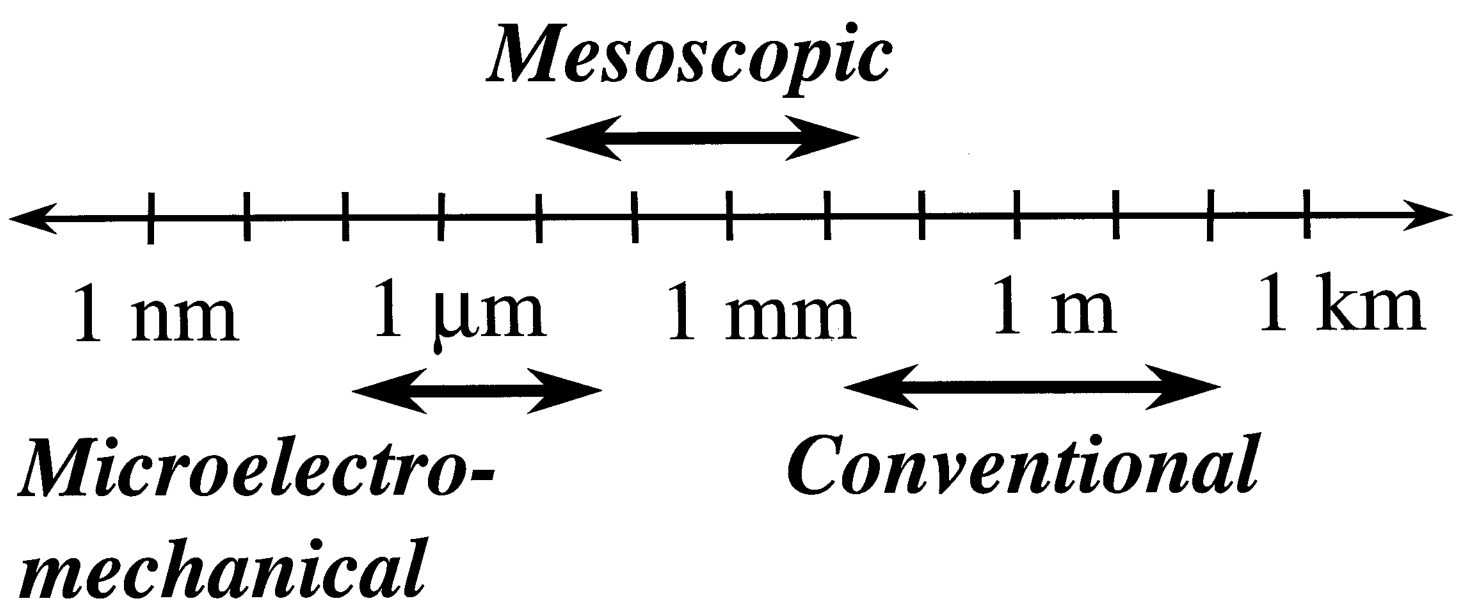
- Multi-Functional Materials
- Electroactive Polymers
- Compact Hybrid Actuation
- Mechanical Enhancement of Human Capability
- Advanced Magnetic Materials
- Spin Electronics
- Molecular Electronics
- Nanostructured Materials -- Applications Driven!
- Small Scale Design and Integration
- Accelerated Insertion of Materials

*Meso*scale Opportunities at DARPA

William Warren

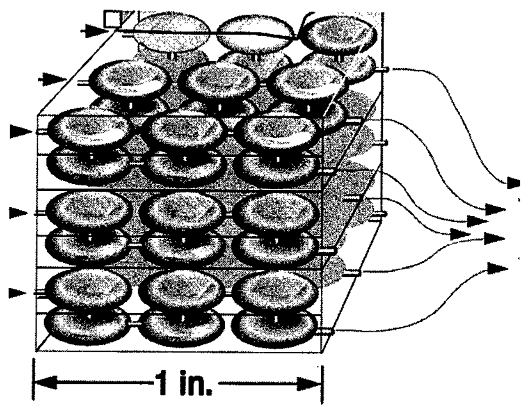
DARPA/DSO

wwarren@darpa.mil

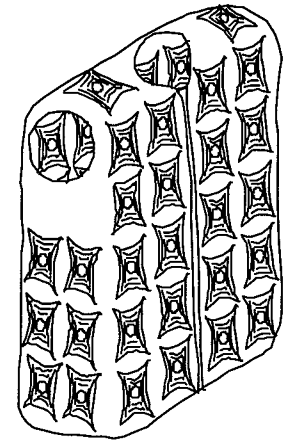


Meso-Machines - *"The Right Size"*-Machines

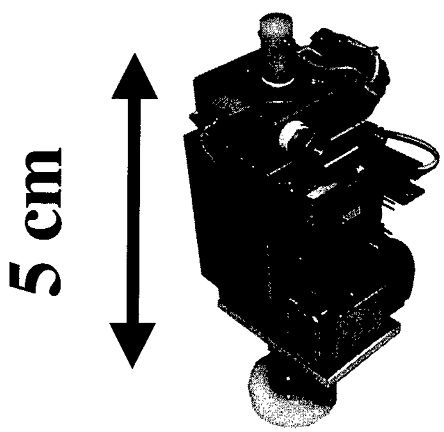
BWD Detection Pumps



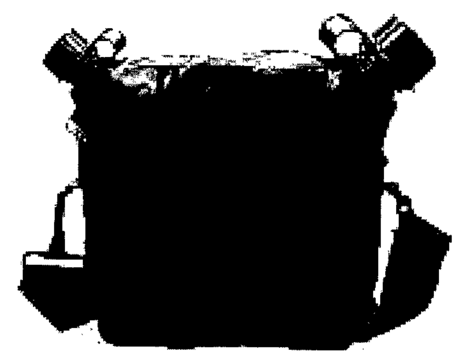
Cool Uniforms



All "terrain" machines

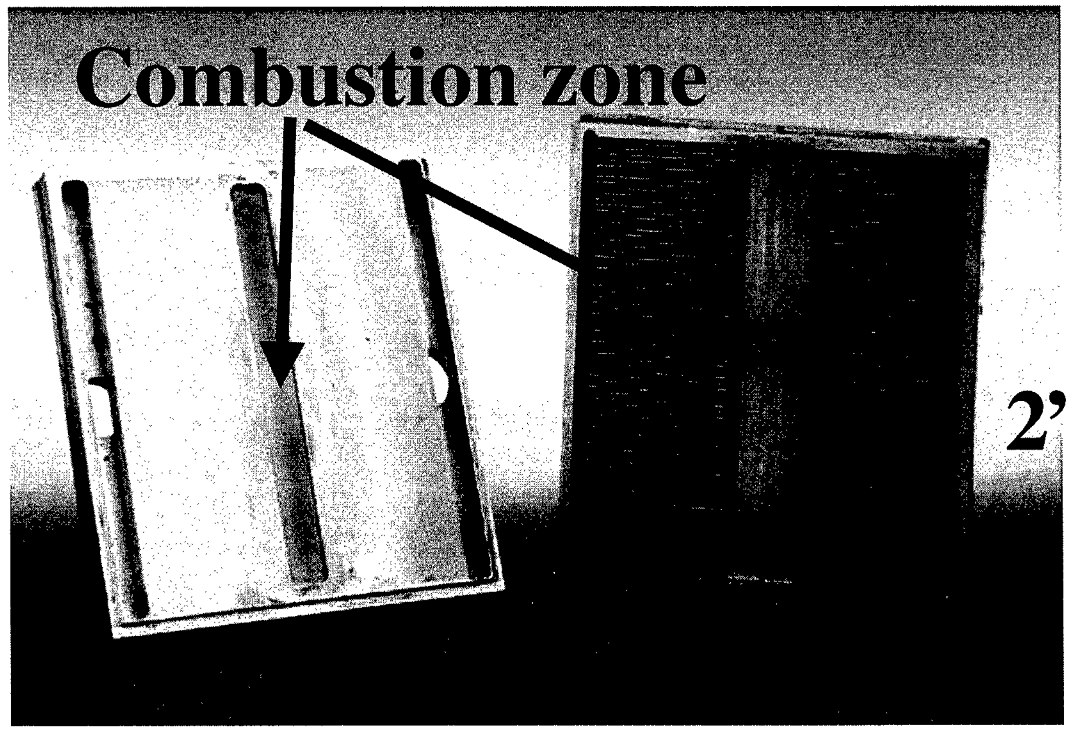


Water Purification and Desalinization



*Why Meso*scale Machines? -

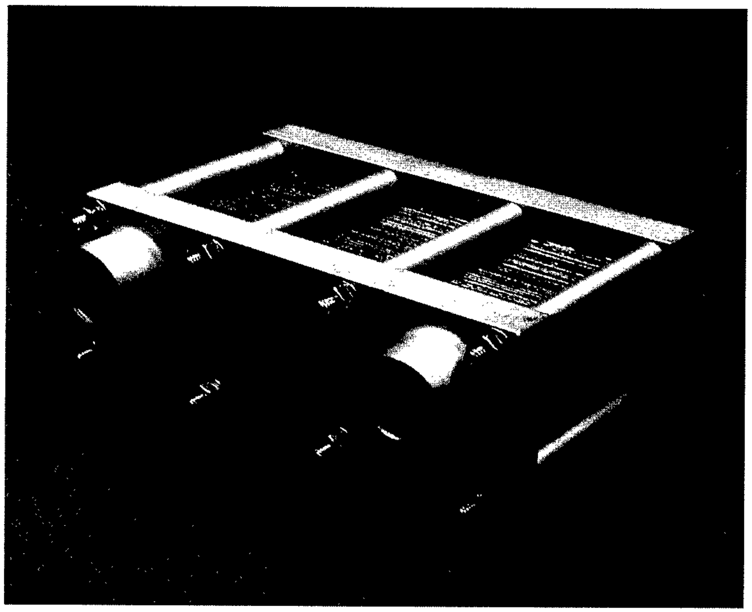
- *Optimum* size for chemistry (combustion)
- *Optimum* size for heat transfer
- *Optimum* size for macroscopic electrostatic actuation
- Improved reliability
- Low cost
- True 3-D shapes

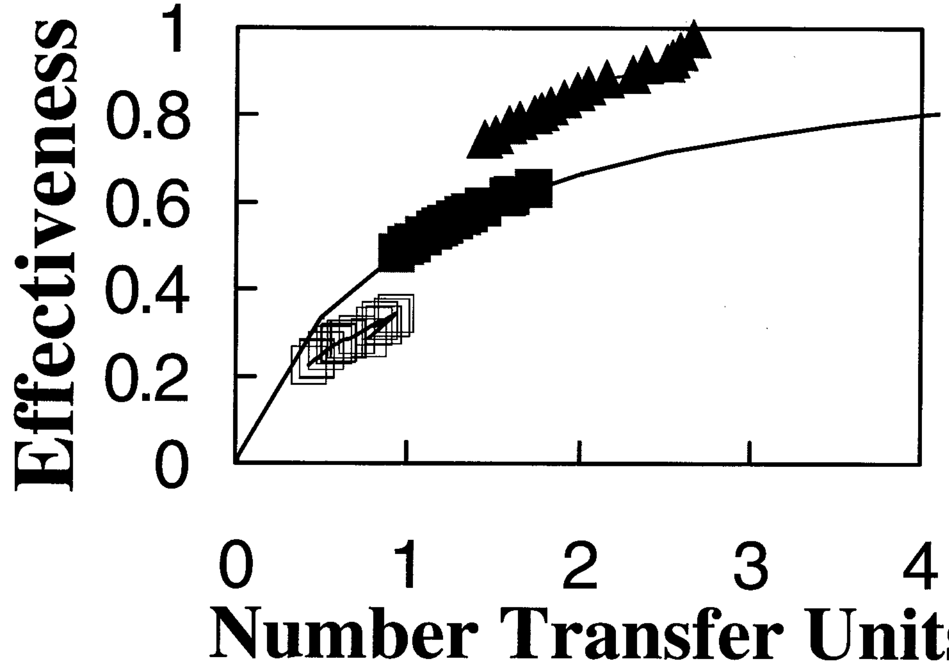


Phenomenal *Meso*-Heat Exchangers

MesoSystems Technology Inc.

- Macro-heat exchangers - 20-30% efficient
- Program start: *meso*-heat exchangers - 50-60% efficient
- Newest *meso*-heat exchangers - 96% efficient

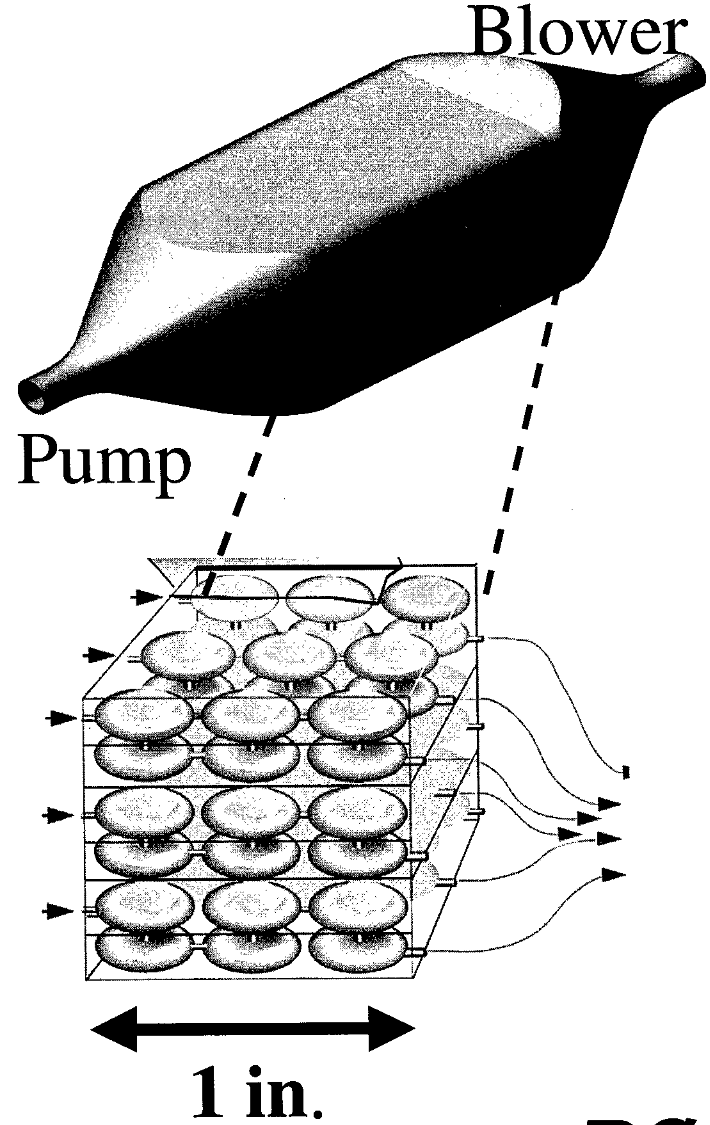




Efficient Multi-layer *Meso*scopic Blowers

Honeywell Technology Center

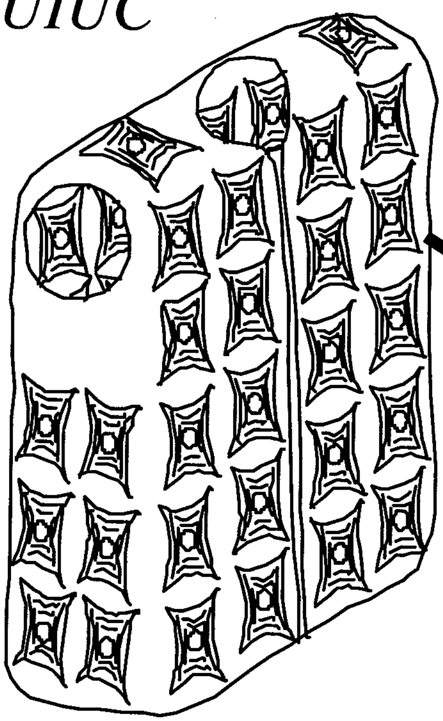
- Macro flow rates ~ 10 l/min
- Figure of merit > 50x conventional pumps
- Pump attributes
  - 1 in^3, 1/2 ounce
  - low-power (2 W), truly 3D
  - inexpensive materials (plastics)
  - simple to fabricate



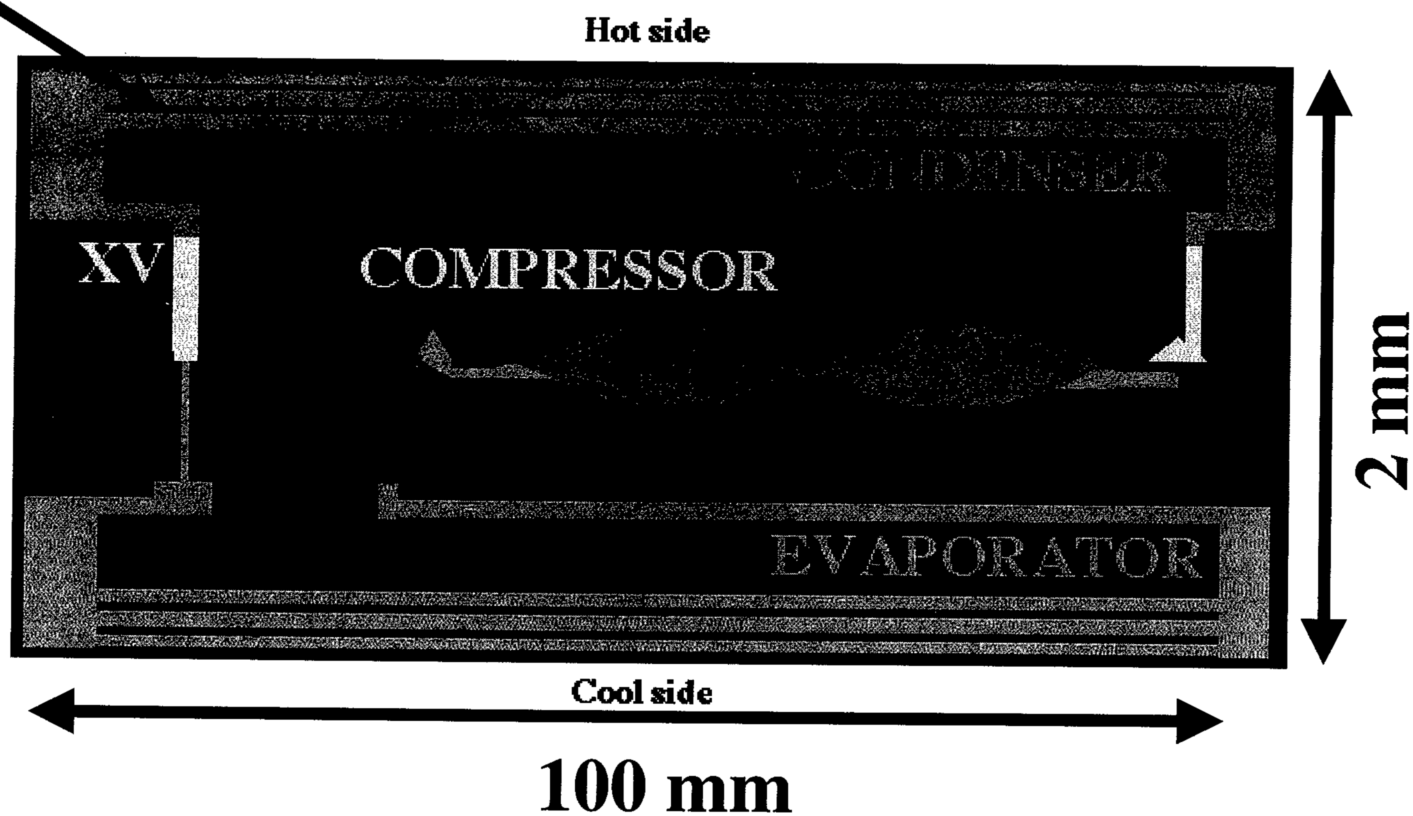
Energy-Efficient Flexible *Meso*-Coolers

DARPA

UIUC



- 1/3 weight of conventional systems
- Heat exchanger optimized at *meso*scale
- Low-power electrostatic *meso*-compressor

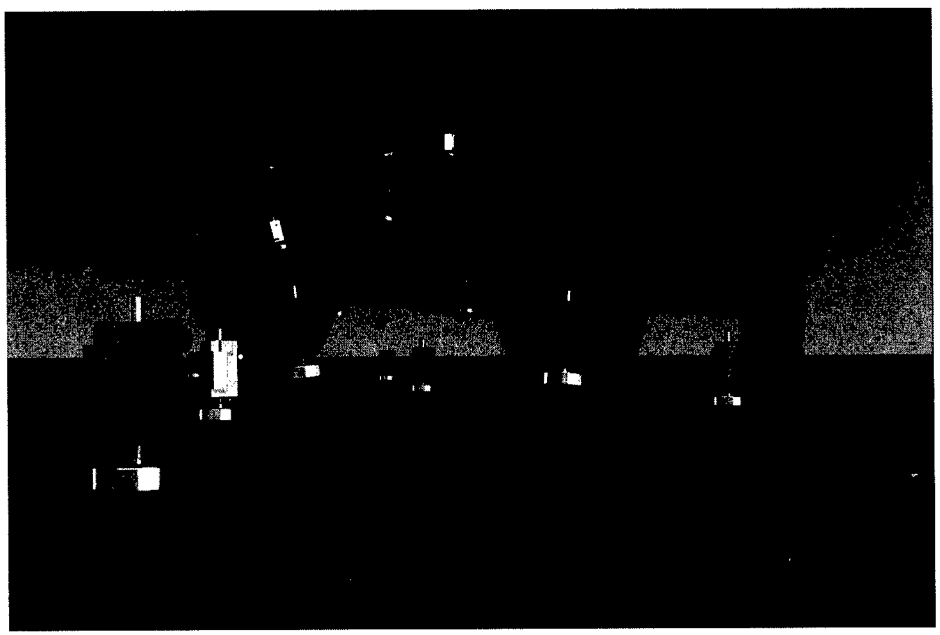


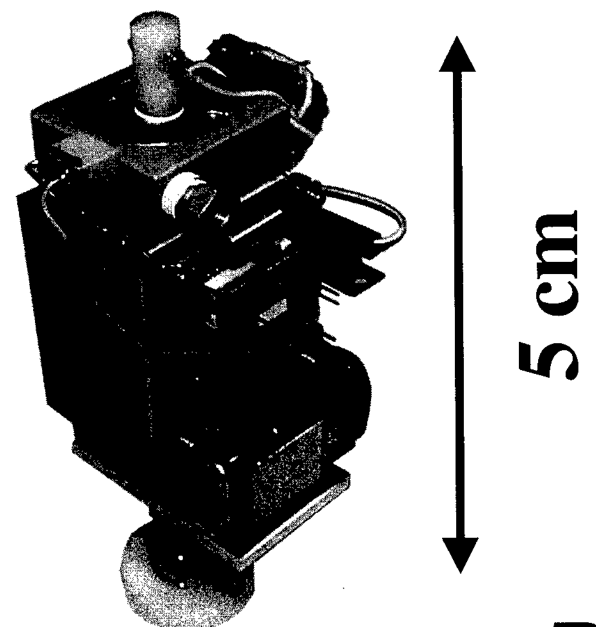
SO

Ingenious *Meso*-Machines Are Hopping

Sandia National Laboratories

- Build a vehicle around power system: 1 mg fuel/hop
- Combustion-powered autonomous hopping
- Exceptional mobility & range capability (10 km)
- Handles rough terrain



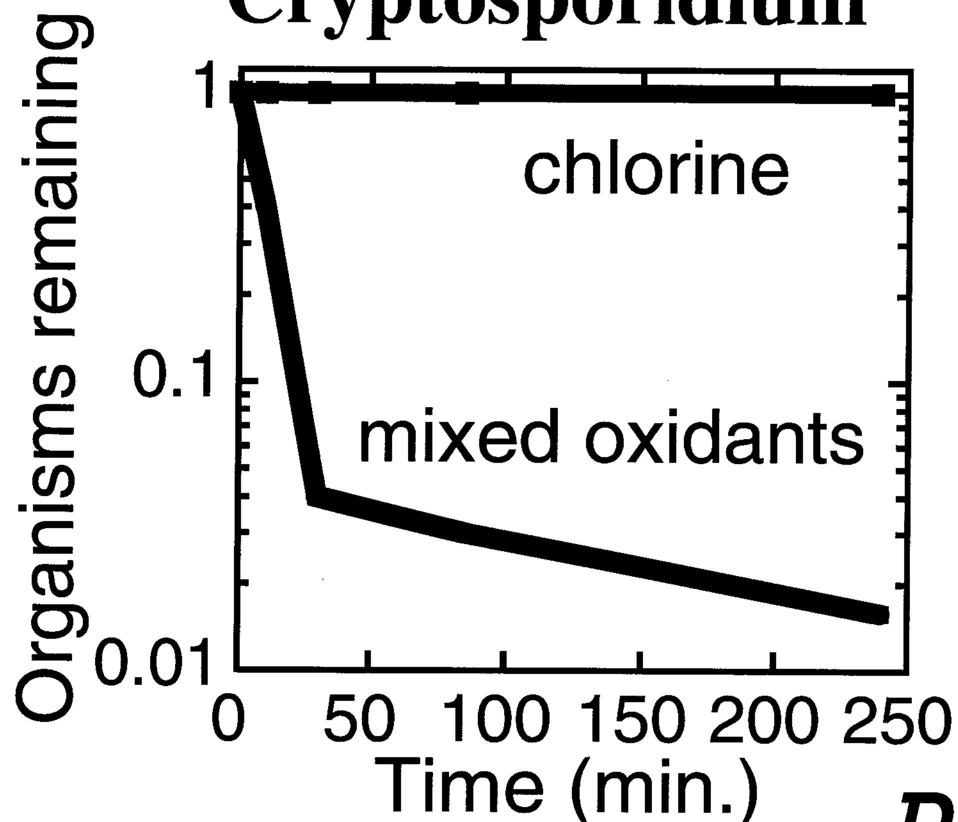


The "Pen" Is MightierThan The Sword!

LATA Inc. & MIOX Corp.

The "pen" creates mixed oxidants that destroy biological and chemical agents by creating ozone, oxy-chloride species, and radicals in an electrochemical cell.

Cryptosporidium



DSO

Water Still the Size of a Coffee Mug

MesoSystems Technology Inc.

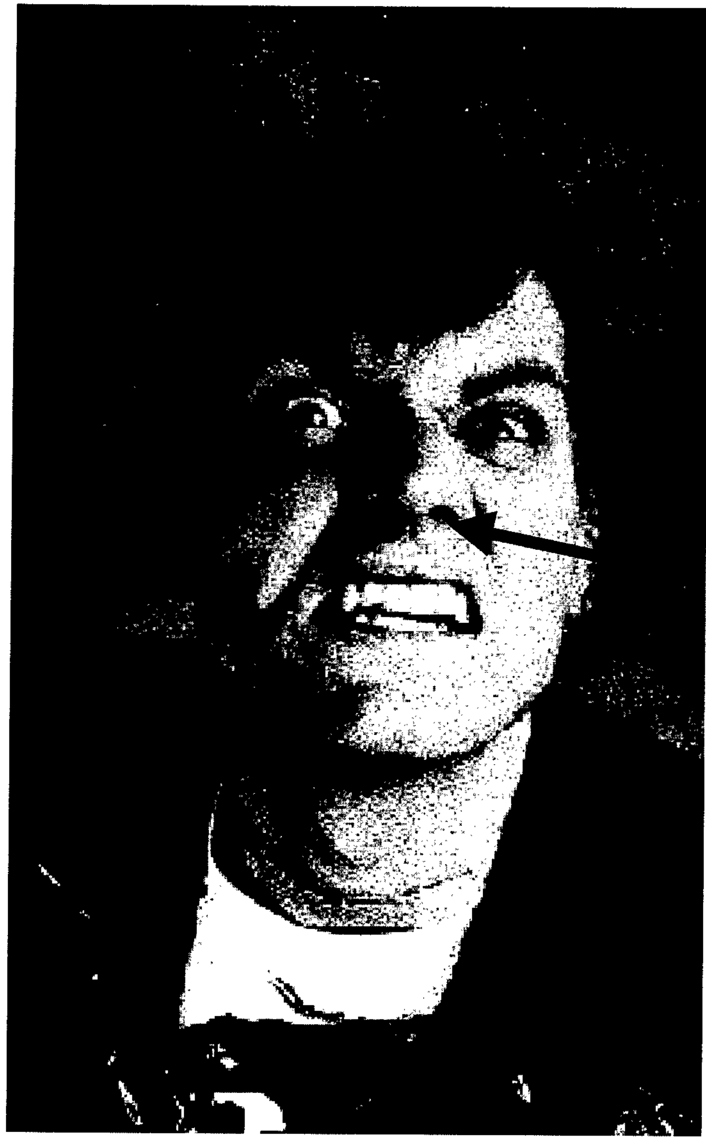
- Size ~ 750 cm^3, weight ~ 0.5 kg
- Fuel = hydrocarbon fuels - no batteries
- Desalinization of seawater (no clogging)
- No BG spores in output water

seawater
0.35% NaCl

distilled water
~ 0% NaCl

DSO

Meso-Channels for Heat Exchange Is Intuitive



MesoFins™

$\dot{Q}$

T_{cold}

Steam Outlet

We Are Envisioning a *Meso*-2000

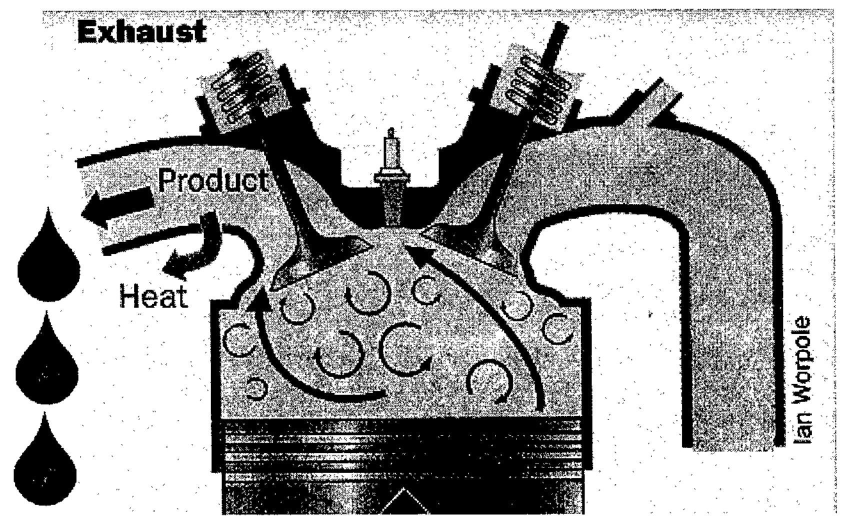
Water generation/testing meso-machines

- Water from combustion by-products
- Biologically inspired (how do dolphins drink?)

Today: condensation of humidity using plastic wrap

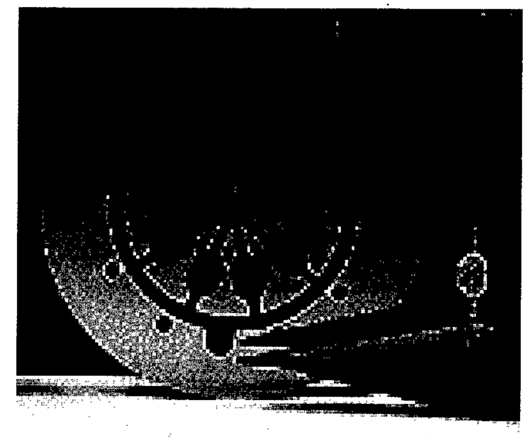
Tomorrow:

$$C_9H_{16} + 13O_2 \rightarrow 8H_2O + 9CO_2$$

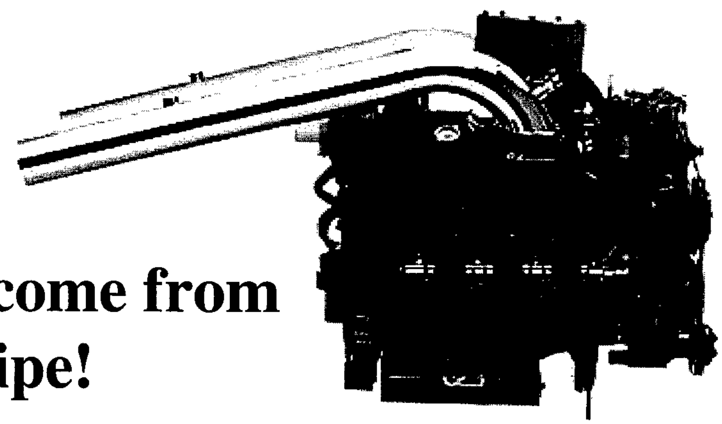


Meso-2000 Concepts

- Meso-chemistry: rapid production of vaccines and pharmaceuticals
- Meso-arrays: waste heat recovery for cooling,water generation and purification

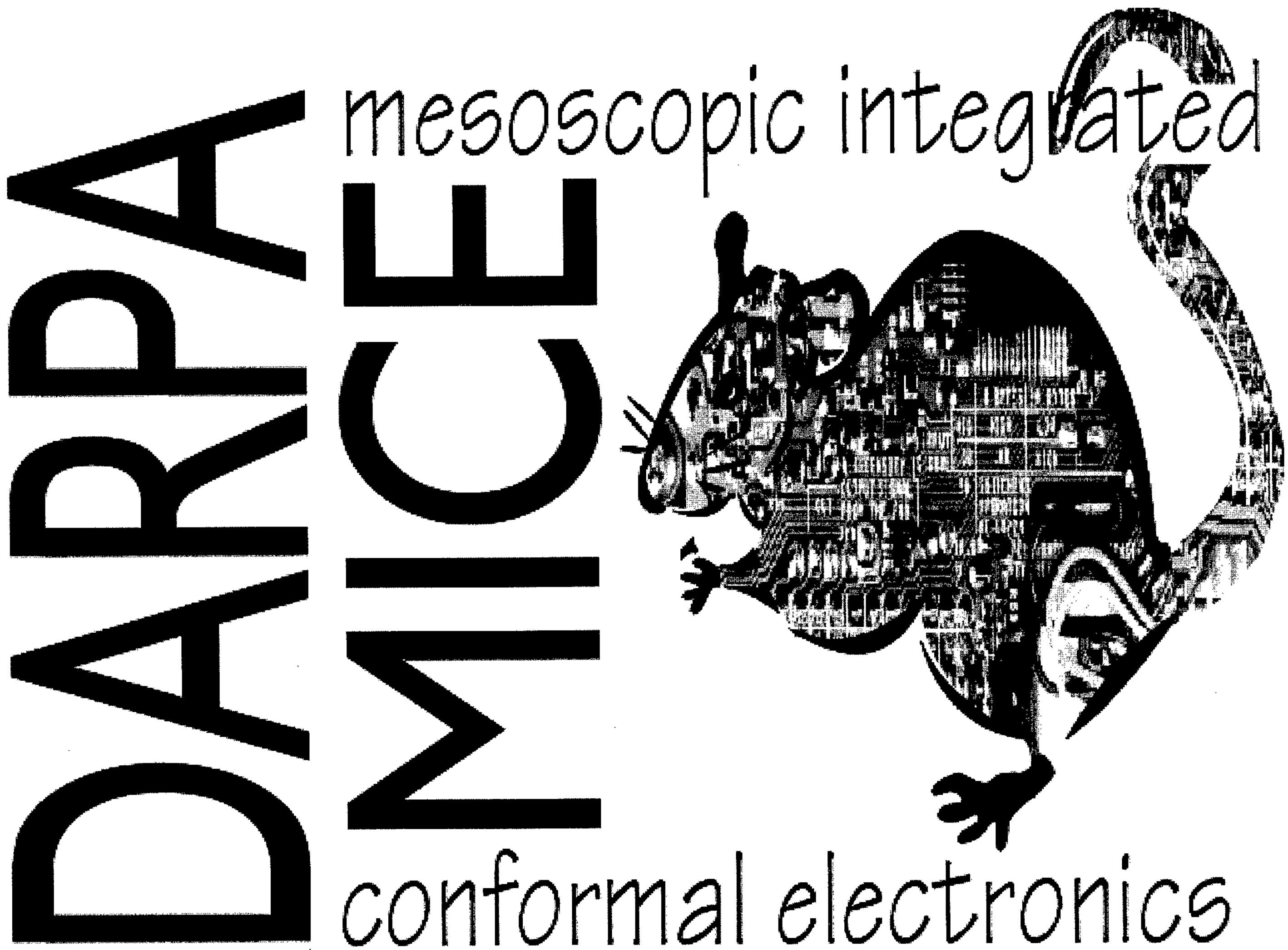


IMM



Good stuff can come from this tailpipe!

Forgotten *Meso*scopic Electronics

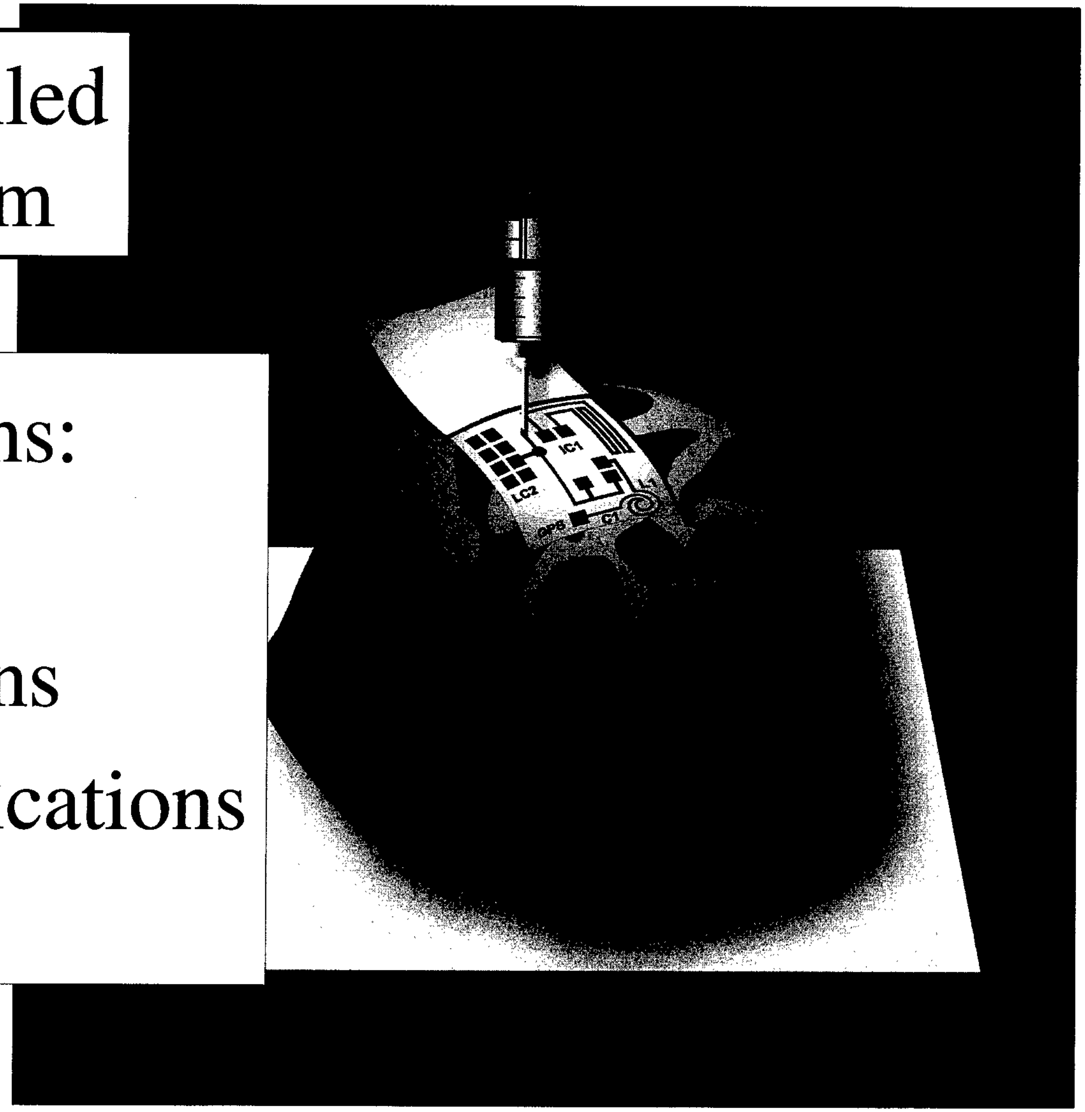


DSO

Warren TECH99

3D Conformal Direct-Write Electronics

Robotically controlled direct-write system

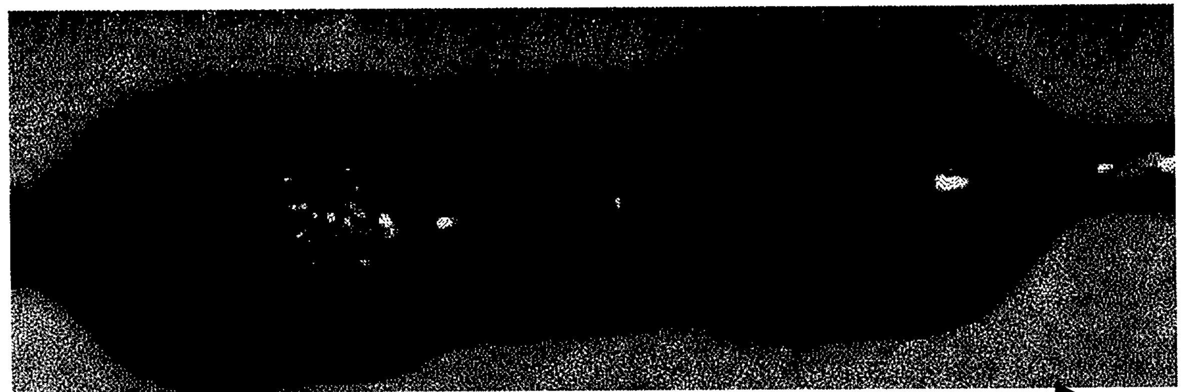


Possible Applications:

- Microsatellites
- Miniature munitions
- Wireless communications
- Security printing

Lilliputian *Meso*-Electronics

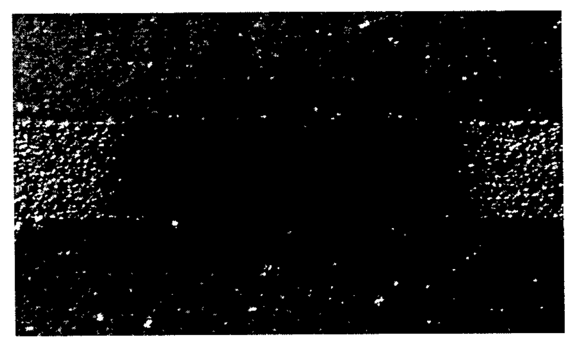
Conventional through-hole mount



6 mm

<u>Direct-Write</u>

- 2 - 4x smaller
- 20x thinner
- No solder
- 300K deposition
- Multilayer



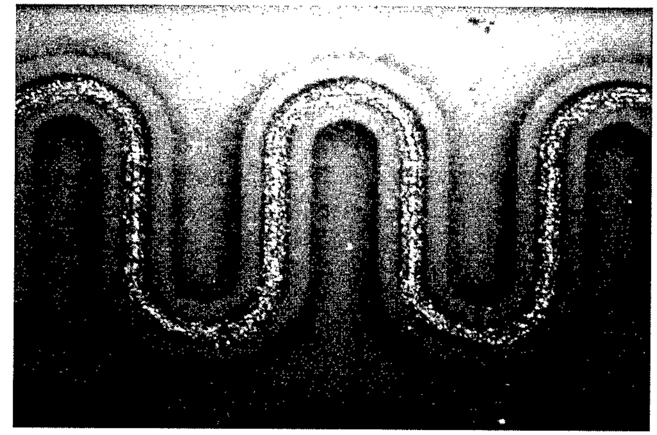
DARPA

Direct-Write Passive Components

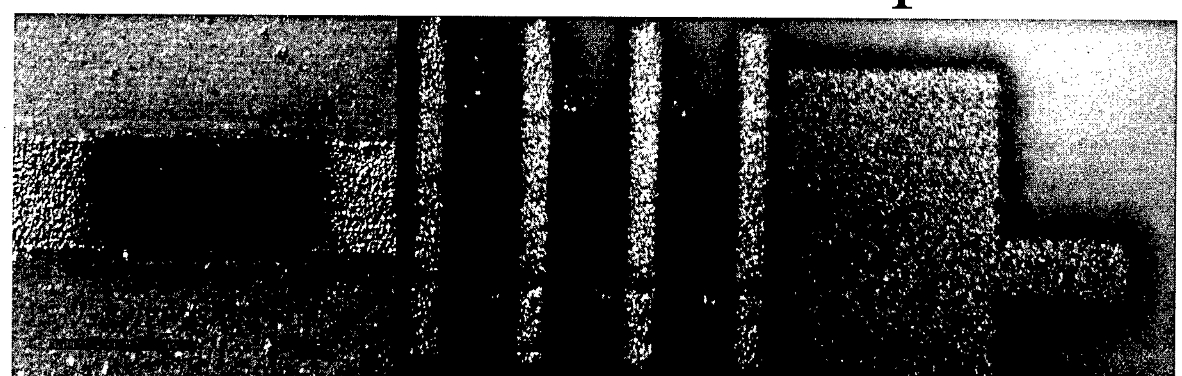
Potomac Photonics Inc./Naval Research Laboratory

- 3-D fabrication
- *in situ* trimming
- Room temperature deposition
- Works with any material
- Conformal

30 μm Au lines



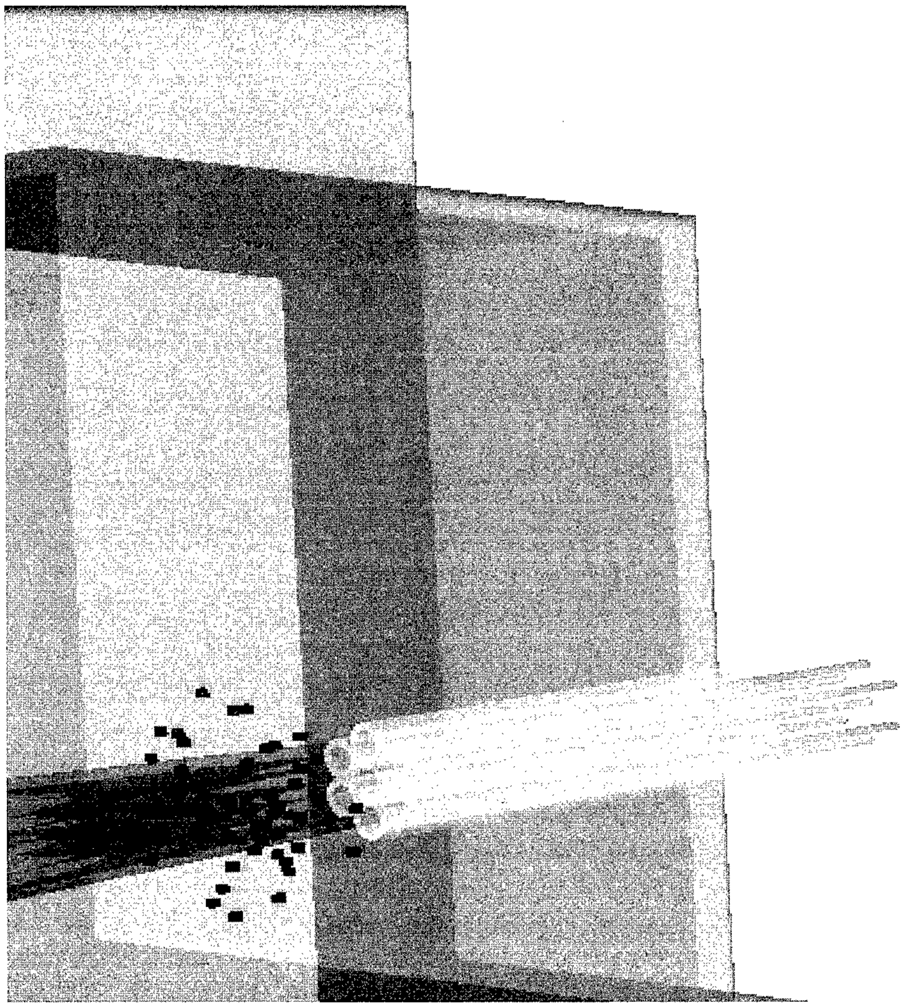
Resistors Inductors Capacitors



Laser Guided Deposition Process

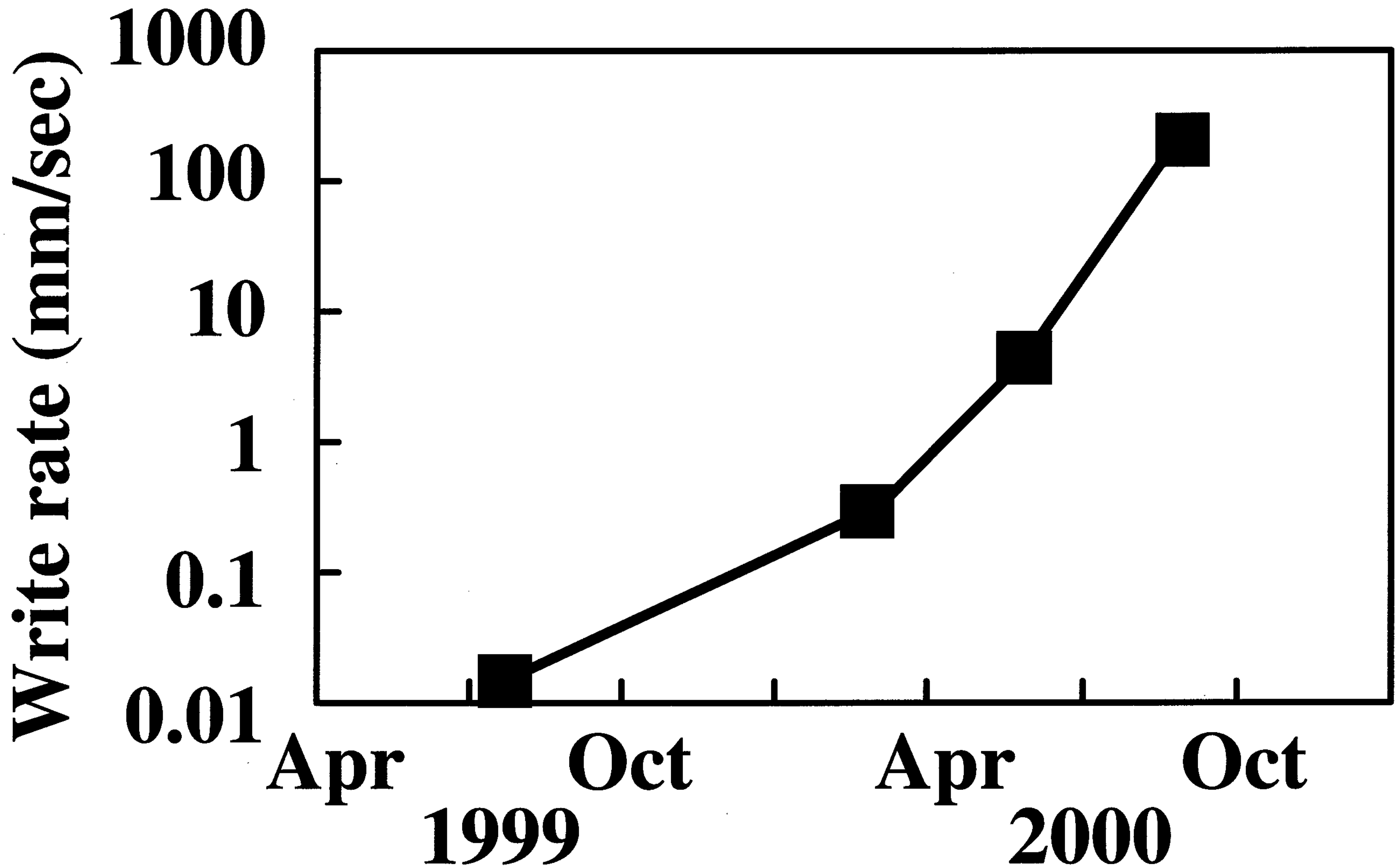
Optomec Design Corp.

Dense Materials on Low Temperature Substrates



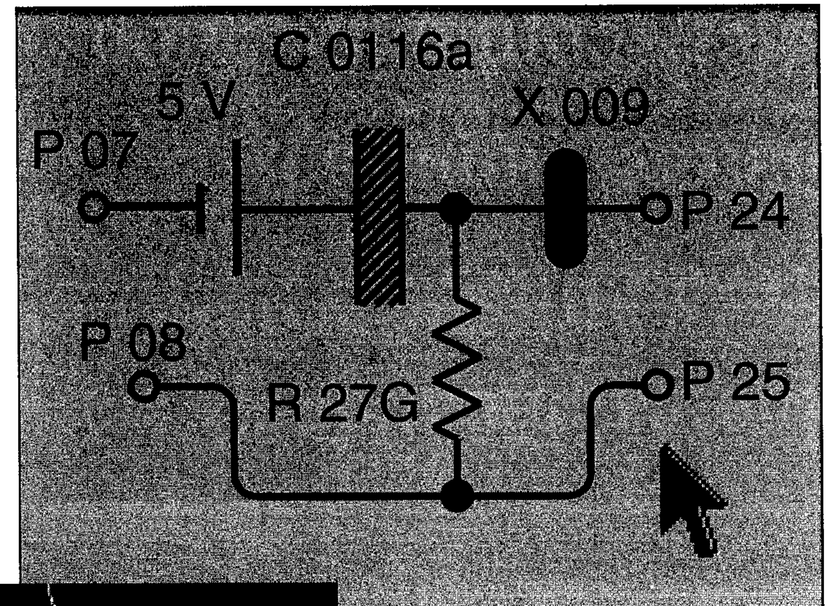
Customers Demand Rapid Manufacture

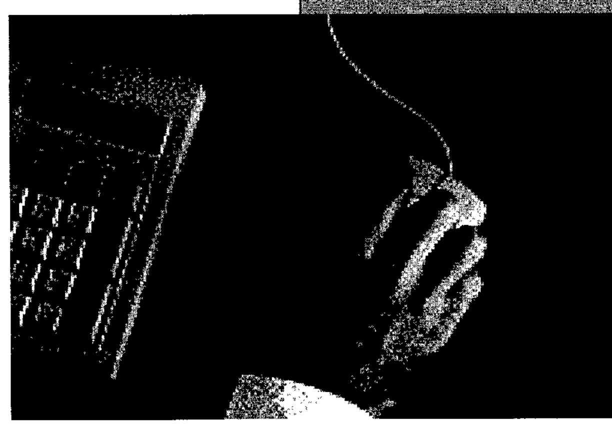
Potomac Photonics Inc.



www.*meso*fab.com

- Host website devoted to *mesoscale* technology
- Tutorials & background information
- Links to team members, end-users, manufacturers
- Updated software, "recipes" and components lists
- Place an order!





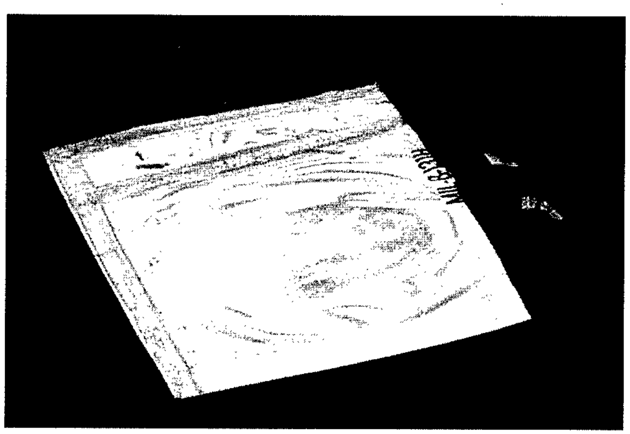
Potomac Photonics Inc.

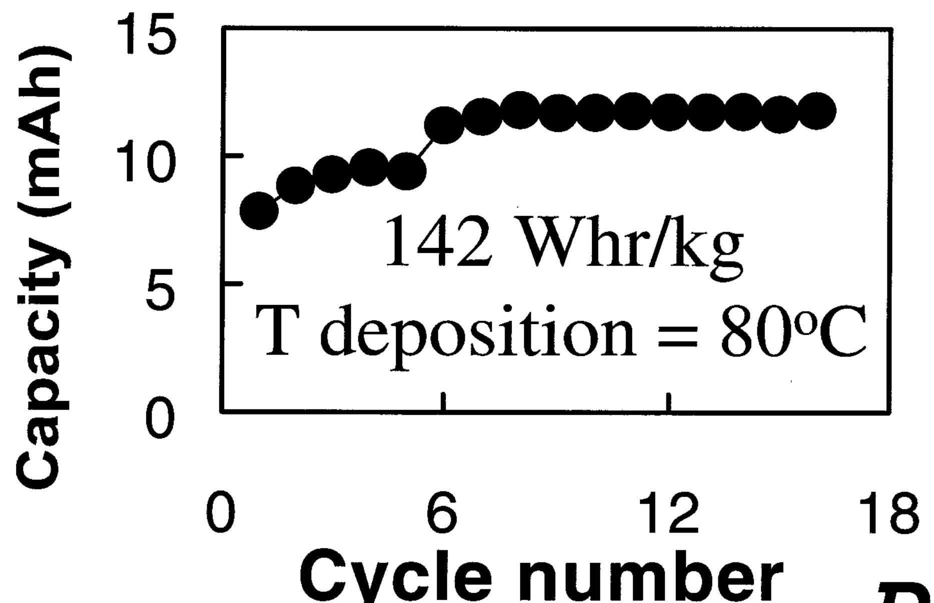
DSO

Batteries are Included!

Batteries, Solar Cells & RF Charge Pumps

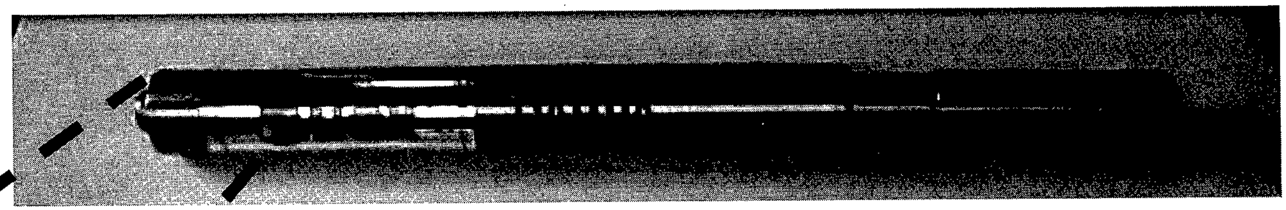
- Reduced weight/improved performance
- Rugged/emplaced on any surface
- Fully integrated with the structure
- Capture incident energy (solar/electromagnetic)



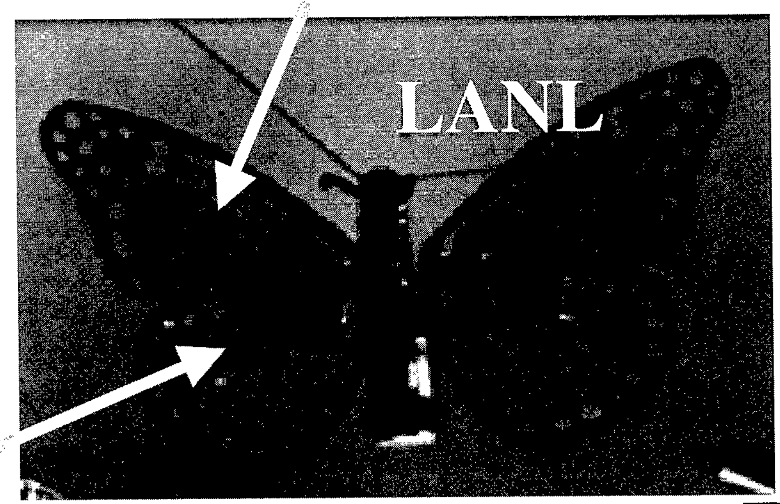


Of MICE and Meso-Machinists

MICE will integrate rugged, miniaturized electronics with meso-machine structures



Passives and circuitry integrated with the structure



Integrated batteries

DSO

Microsystems Technology Office (MTO)

DARPATech 1999

Dr. Noel MacDonald, Director

MTO

- Microsystems via 'Chip-scale' Integration of Core Technologies:
  - –Electronics
  - –Photonics
  - –MEMS (Microelectromechanical Systems)

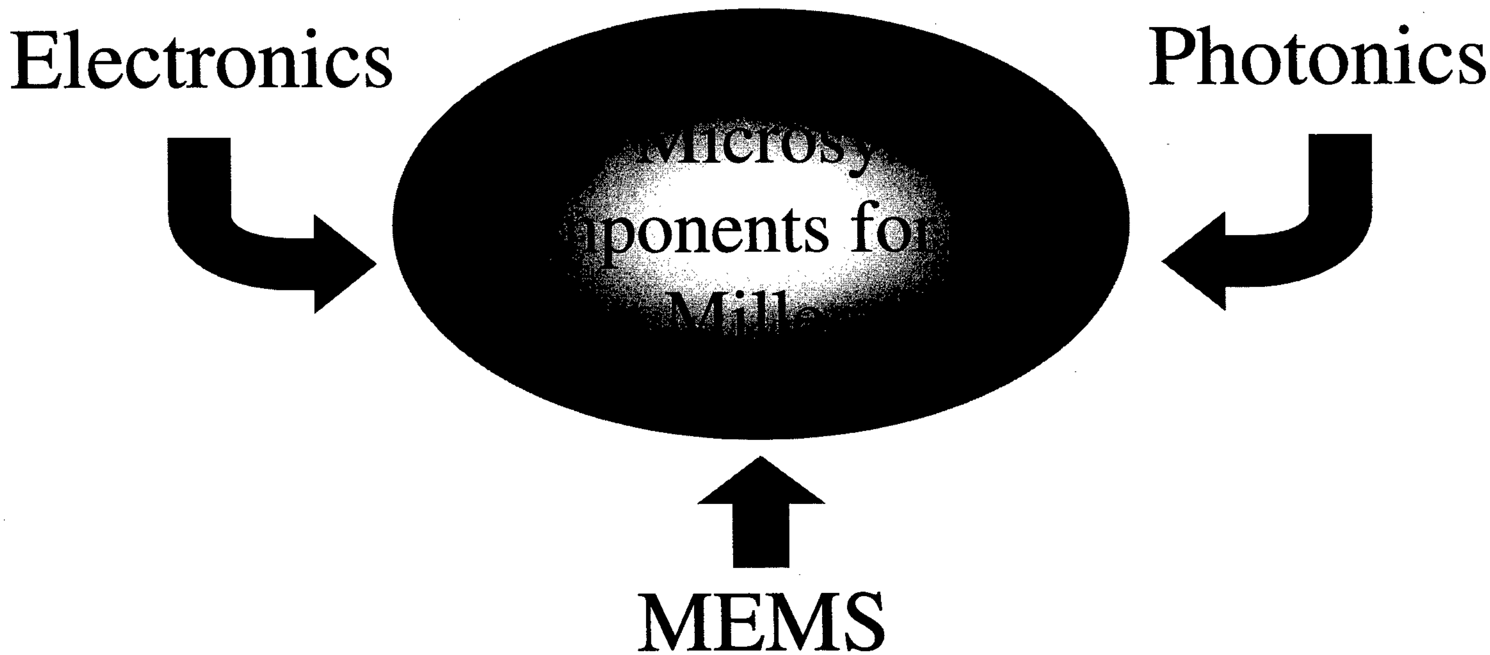
MTO (cont.)

- Materials, processes, devices & supporting technologies for chip-scale integration of Core Technologies

MTO Support Programs

- CAD (Computer Aided Design) for heterogeneous integration
- Simulation tools for ‘chip-scale’ microsystems
- Advanced Lithography

Microsystem Technology

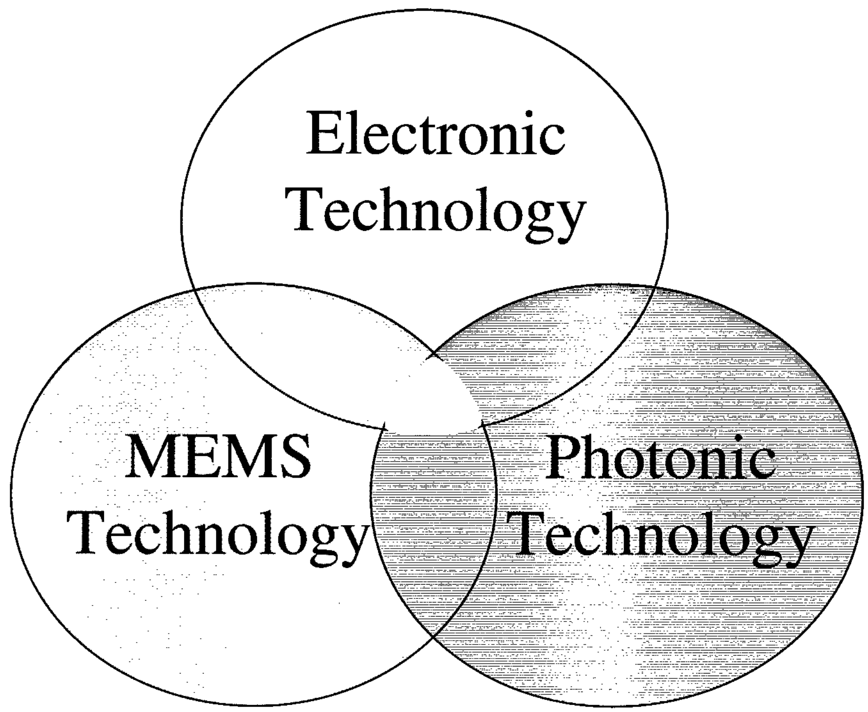


'Chip-scale' heterogeneous integration

DARPA

No Boundaries

MTO



The ‘new gold’ is found at the intersections of the 3 technologies

DARPA

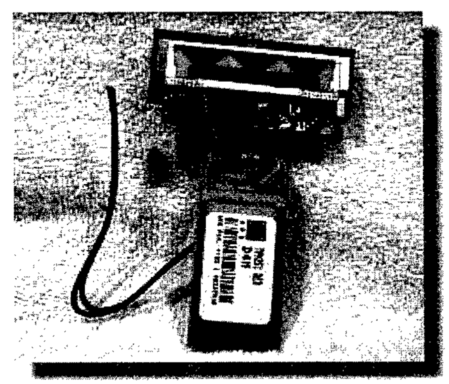
Commercial Examples:

MTO

'Chip-scale' Heterogeneous Integration

<u>Ink Jet Printer Head:</u>

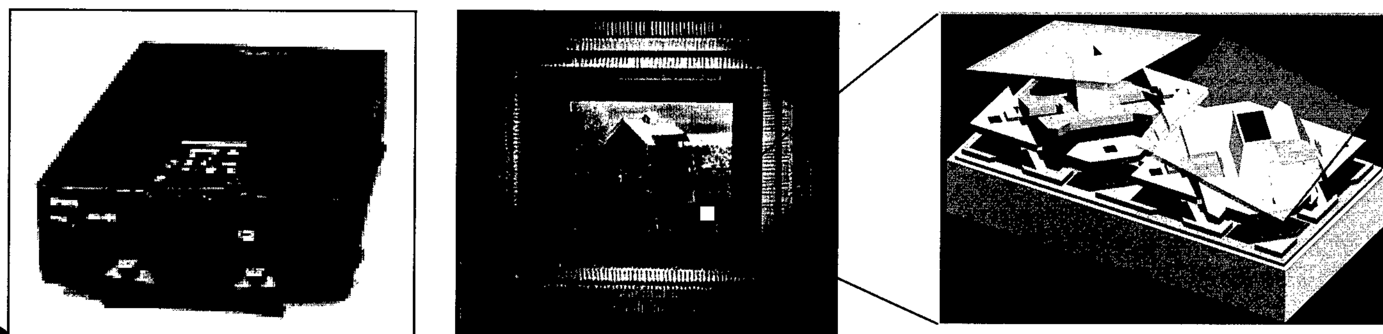
(Microelectronics/MEMS)



Commercial Examples:

'Chip-scale' Heterogeneous Integration

<u>Texas Instruments Digital Micromirror Device (DMD)</u> TM: (Microelectronics/ MEMS to direct photons)

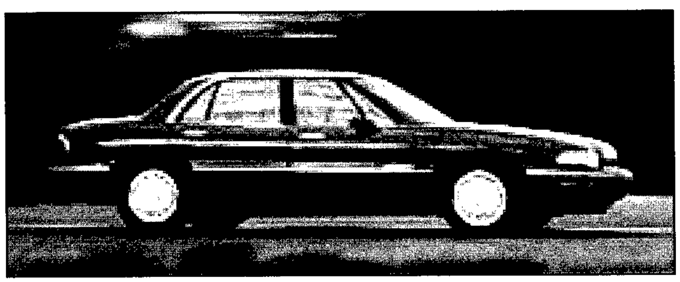


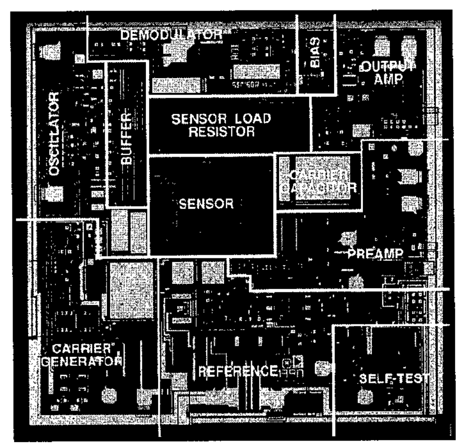
Commercial Examples:

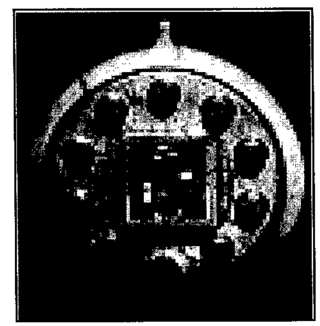
‘Chip-scale’ Heterogeneous Integration

<u>Micro Accelerometer (Airbag Deployed):</u>

(Microelectronics/MEMS)







DARPA

Microsystem Technologies

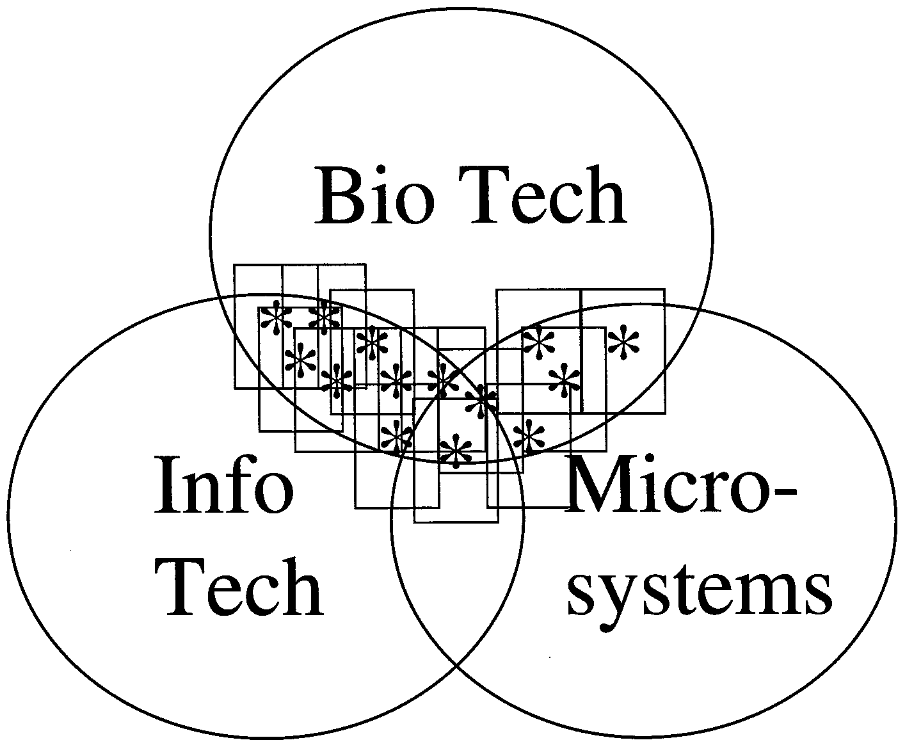
MTO

Focus on the "I Word" - Integration at the micro/nm scale

- Processes
- Contacts, isolation and interconnects
- Mixed materials and mixed technologies
- Multiple chip integration (not packaging)

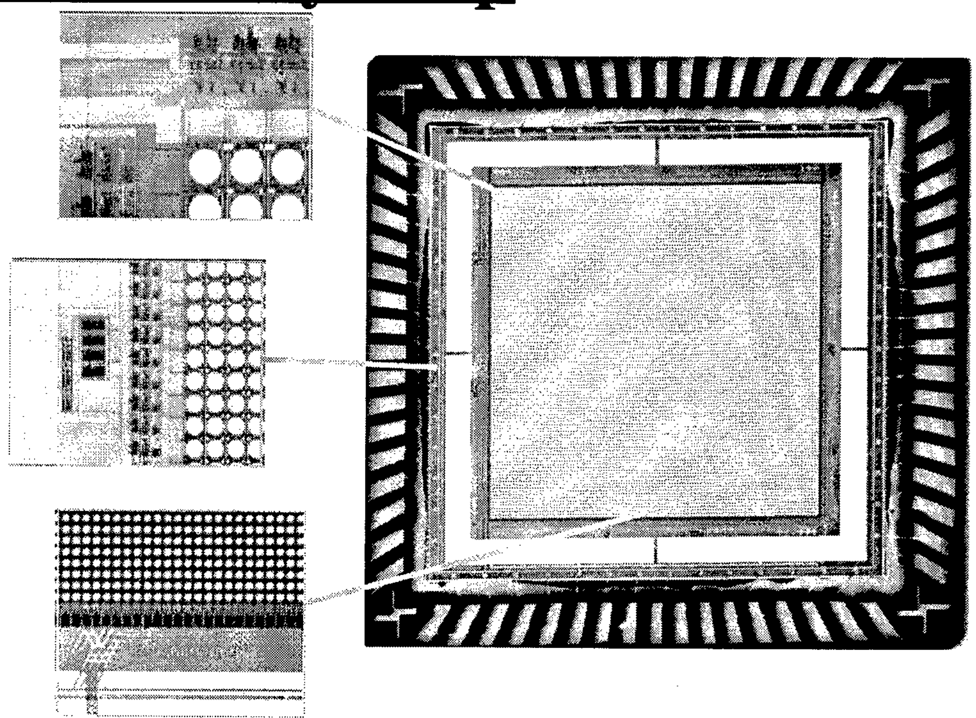
DARPA MTO

Exploring the Interface between Biological Technology and More Conventional DoD Technologies



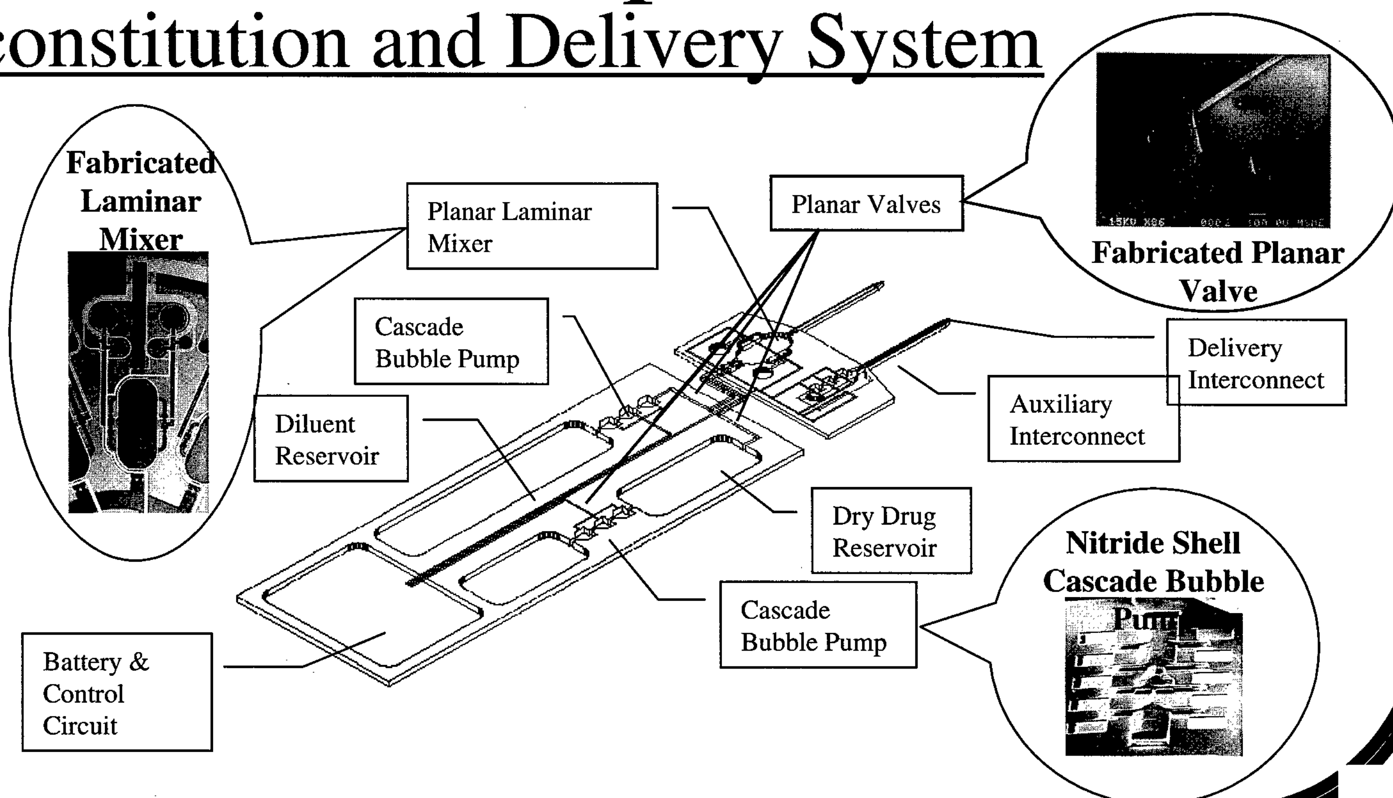
Biological Technology Examples

10,000 Site Assay Chip

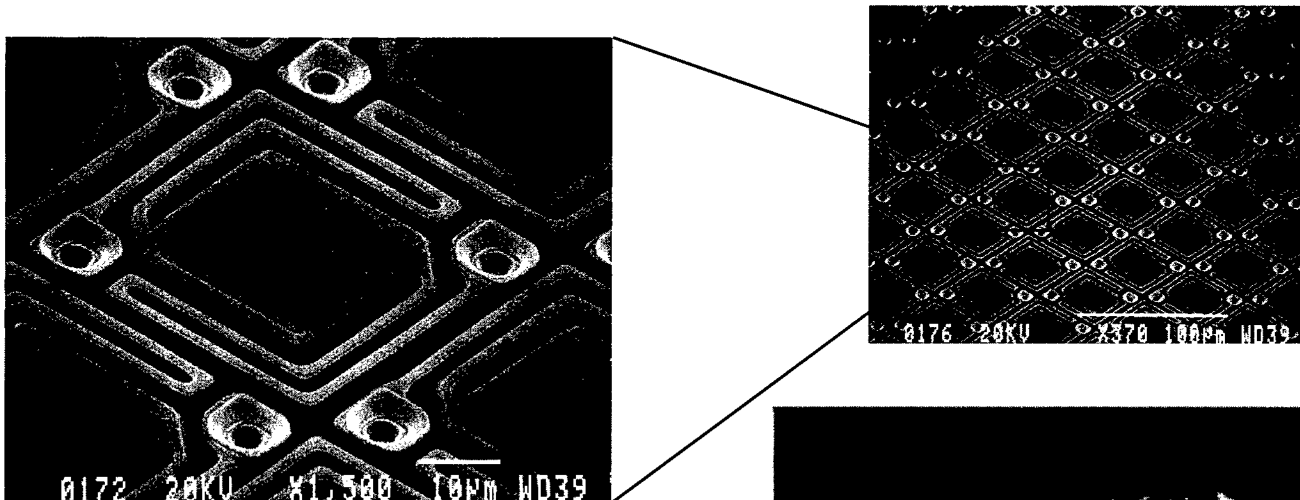


Biological Technology Examples

Reconstitution and Delivery System



Photonic Imaging Examples



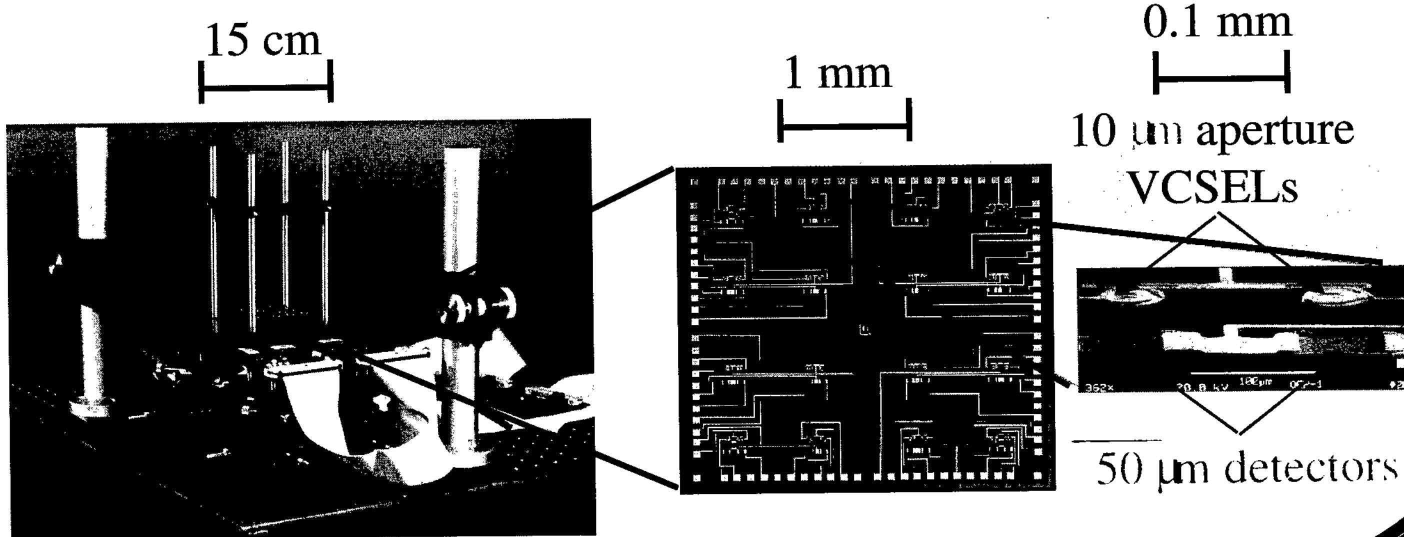
Single-Frame @ f/2.2 (50% Trans)

Raytheon

Photonic Technology Examples

<u>Free-Space Interconnect Demo:</u>

First system level demonstration of integrated 2-D interleaved arrays of VCSELs and detectors (1/98)



Warfighter Support MTO Programs

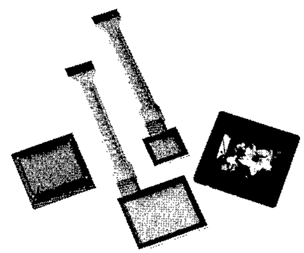
Test cases for microsystem technologies

- Wearable microsystems
- Micro-scale human interfaces
- Small size
- Micro-UAV
- cm^3-scale robot

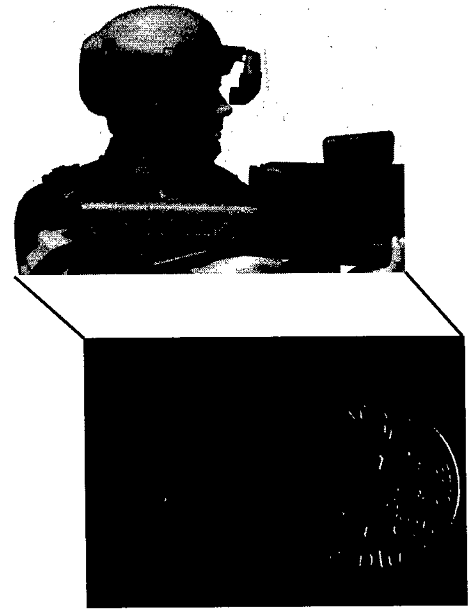
Warfighter Technology Examples

Small Image Sources:

1280 x 1024 high brightness AMLCD for Comanche



640x480 AMEL for Land Warrior



Members of the Team:

DARPA, SSCOM, CECOM-NVESD, ARL, USARARL, Armstrong Labs, NAWC Kopin Corp, Planar Inc., Sarnoff Corp., Allied Signal, Thesys, UMC, MIT-LL, U of Fl, GTRI, GIT, Oregon Graduate Institute, Honeywell, Hughes, Kaiser

DARPA MTO

Summary

- 'Chip-scale' integration of microsystem technologies
- Heterogeneous integration of electronics, photonics & MEMs.
- 'Bio Chips' signal a new era of heterogeneous integration

DARPA MTO

Summary (Cont.)

- Micro-components for new systems & new system architectures
- High-profile commercial products have demonstrated the power of heterogeneous integration

Photonics Overview

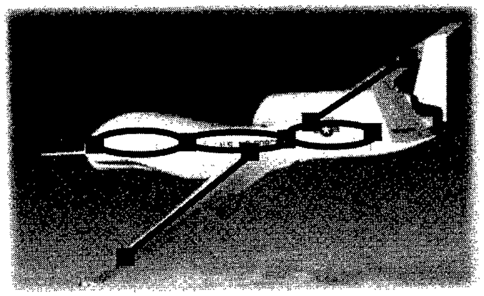
LtCol David A. Honey
DARPA/MTO

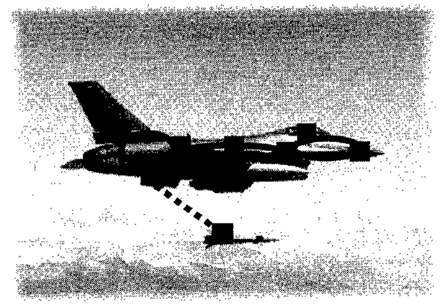
DARPATECH 1999

Photonics

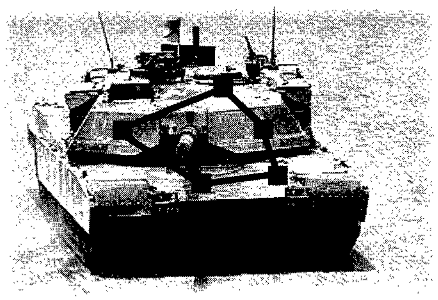
- A Technology for...
  - –Sensing
  - –Communicating
  - –Information Processing

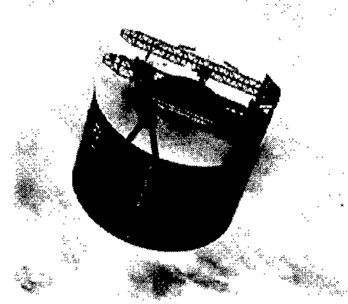
Warfighter Benefits

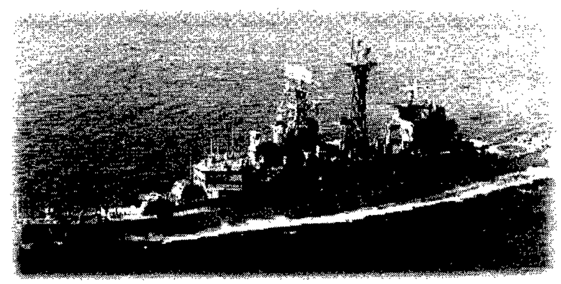




- Comprehensive Awareness
- Precision Engagement







DARPA

Photonics Overview

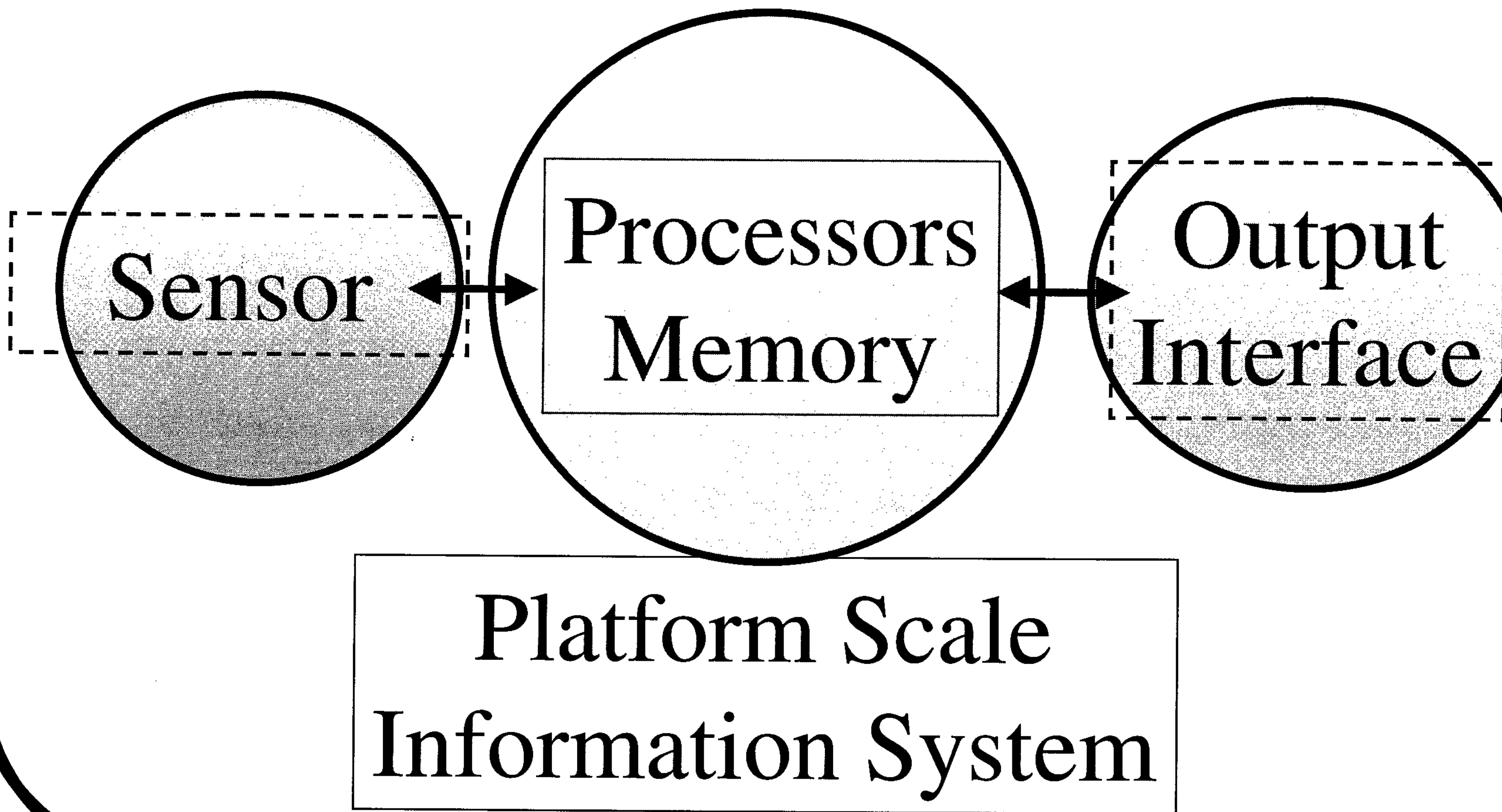
MTO

- MTO Applications Areas
- Technical Strategy: *Business Plan*
- S&T Acquisition Strategy
- Future Opportunities

Photonics Overview

- Technical Strategy: *Business Plan*
- Technology Investment Strategy
- Future Opportunities

Sensor System



DARPA MTO

Programs

- Sensing
  - IR Sensitive Materials; Sensor Integration; GaN Sensors
- Communicating
  - RF Photonics; Optical Micro Networks; Steered Beams
- Processing
  - VLSI Photonics; Photonic A/D Converter

Program Managers

- Sensing
  - R Balcerak; E. Towe; R. Leheny
- Communicating
  - R. Leheny; D. Honey
- Processing
  - E. Towe; R. Leheny

Photonics Overview

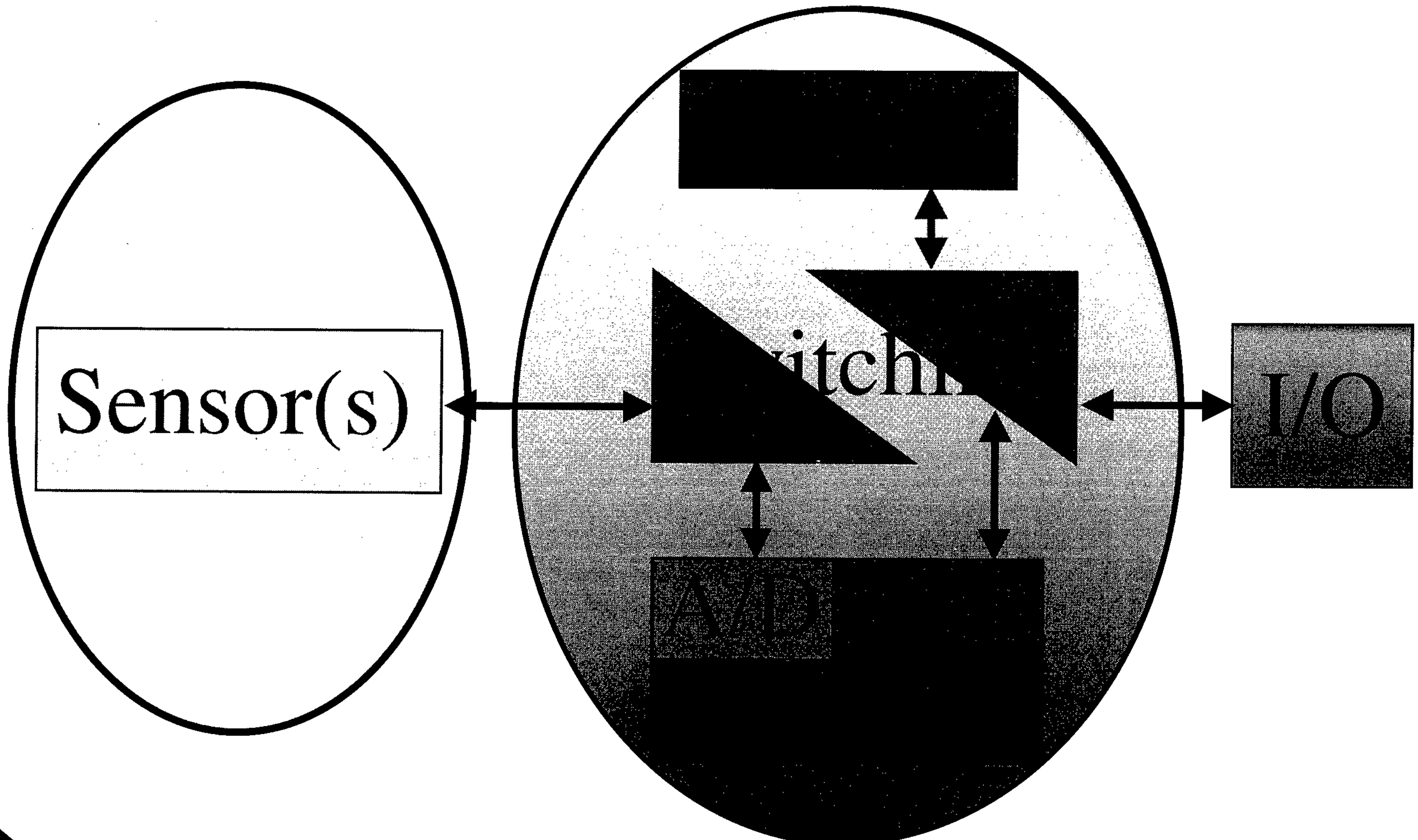
MTO Applications Areas

[redacted]

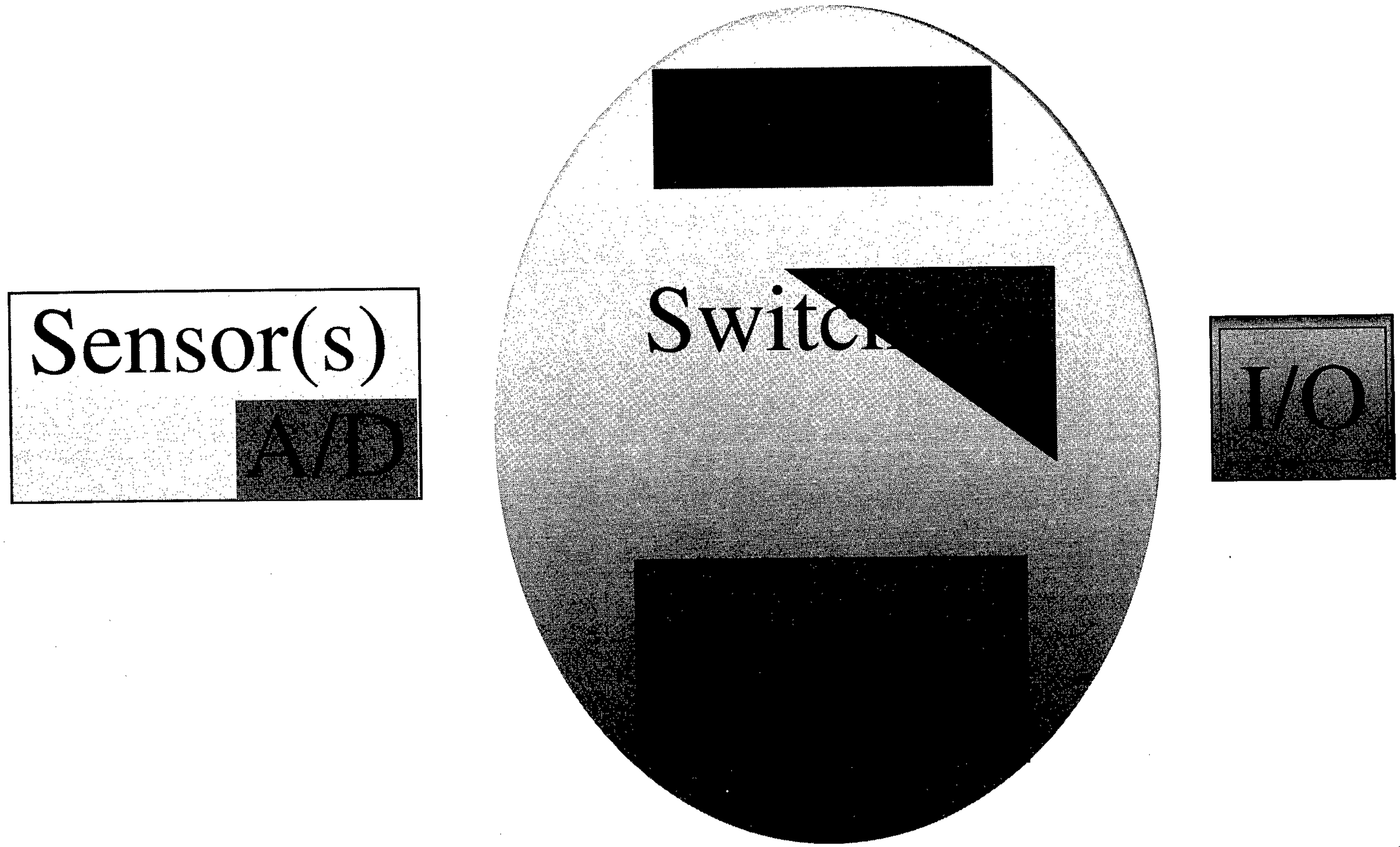
Technology Investment Strategy

Future Opportunities

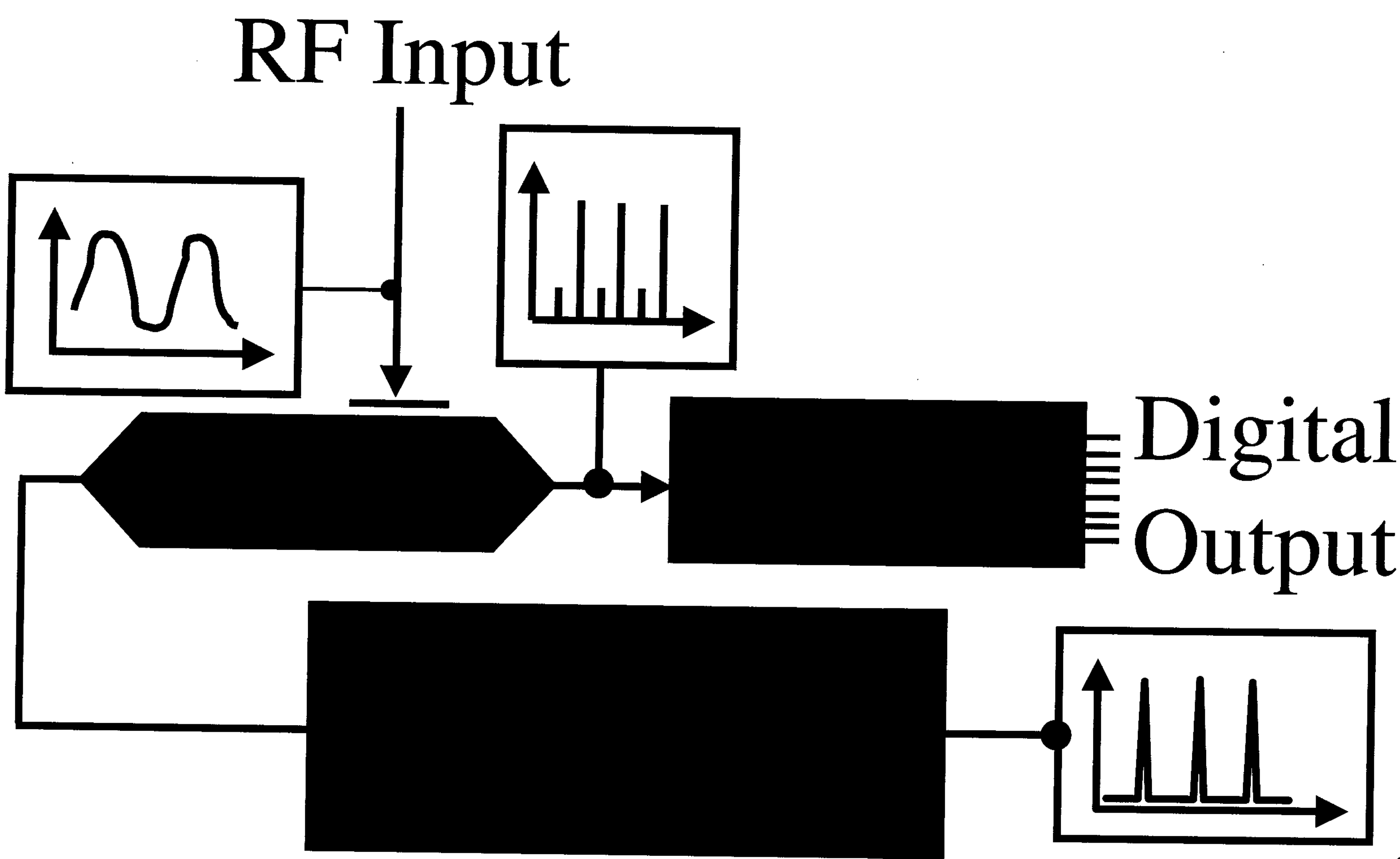
Architecture



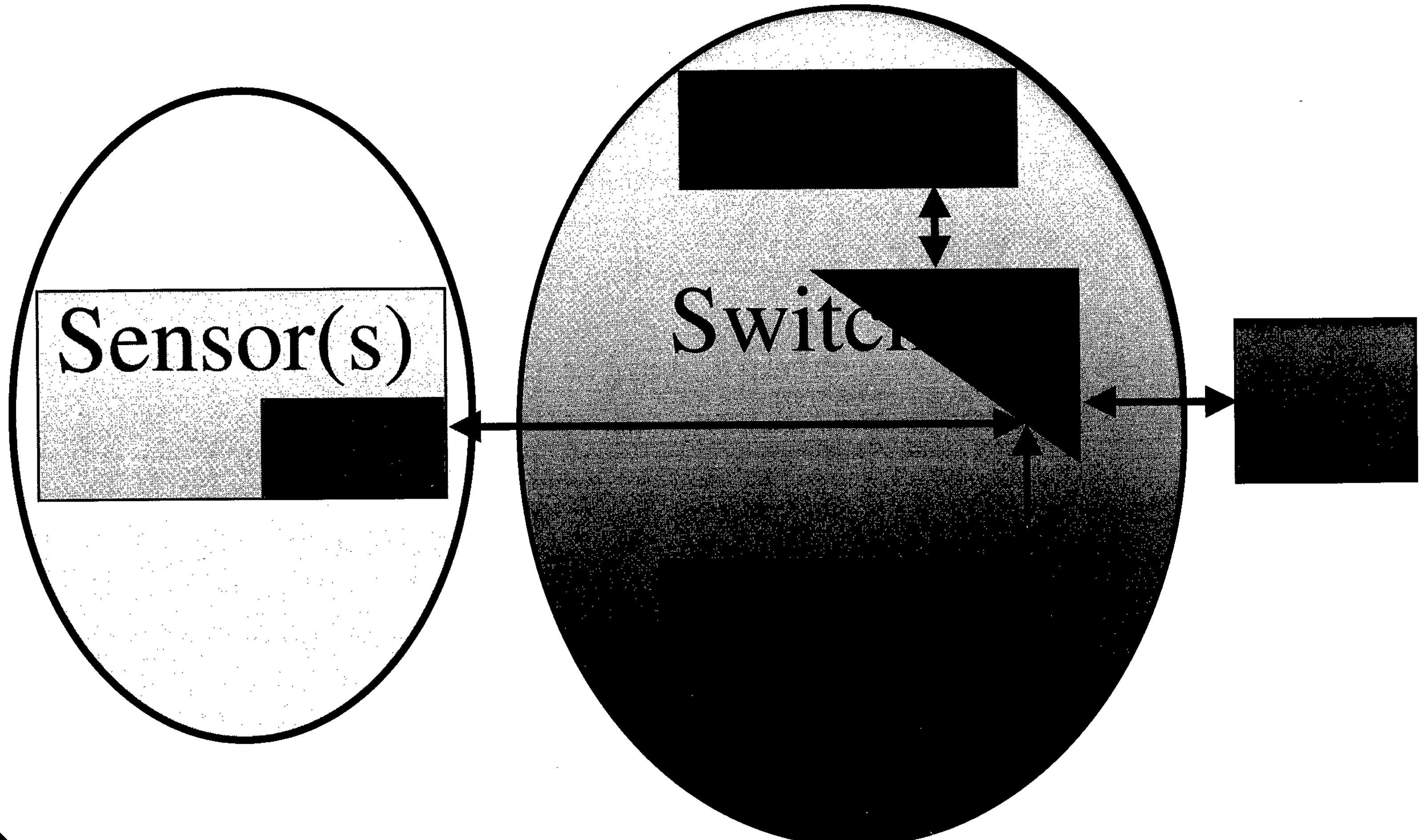
Photonic A/D Converter



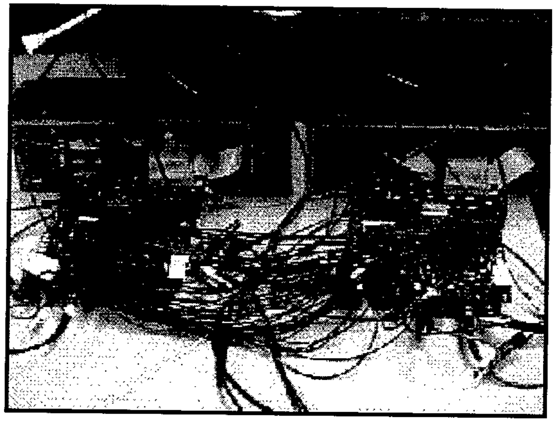
Photonic A/D Converter



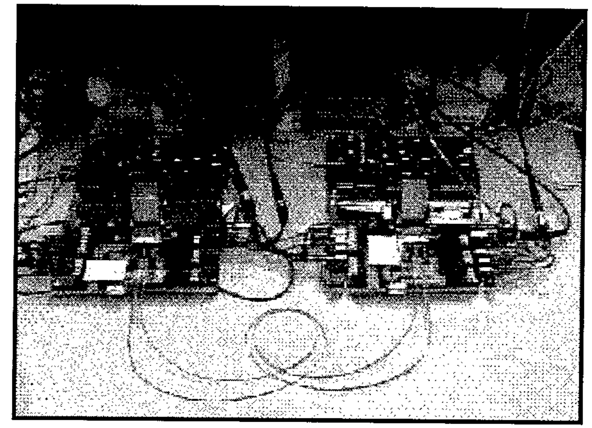
Optical Micro Networks

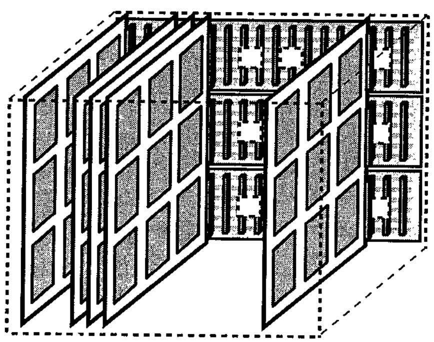


Optical Micro Networks

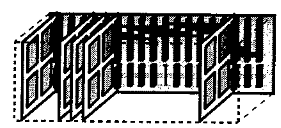


Reduced Cabling





9U chassis

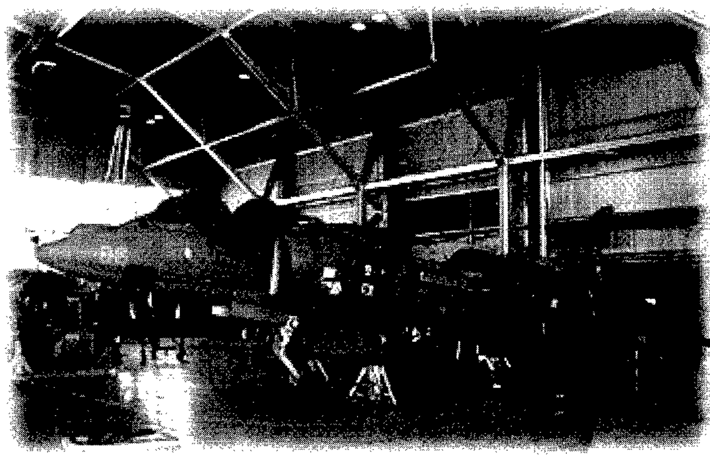


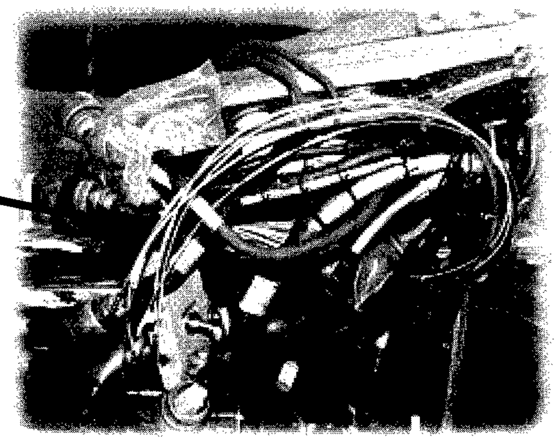
6U chassis

DARPA

MTO

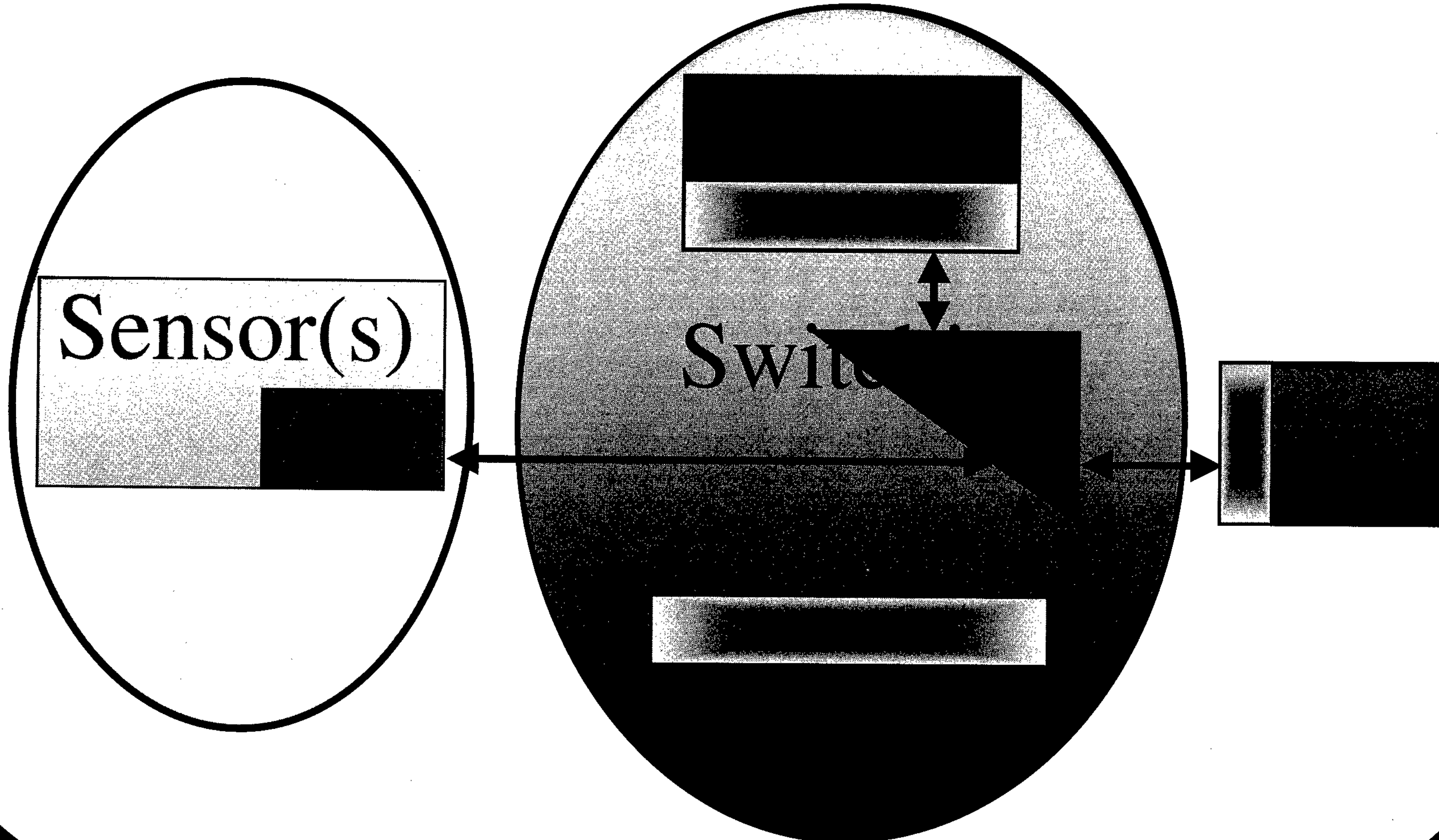
AV-8 Flying Testbed





China Lake NAS

VLSI Photonics



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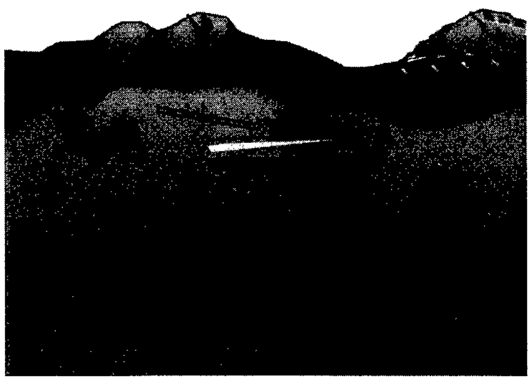
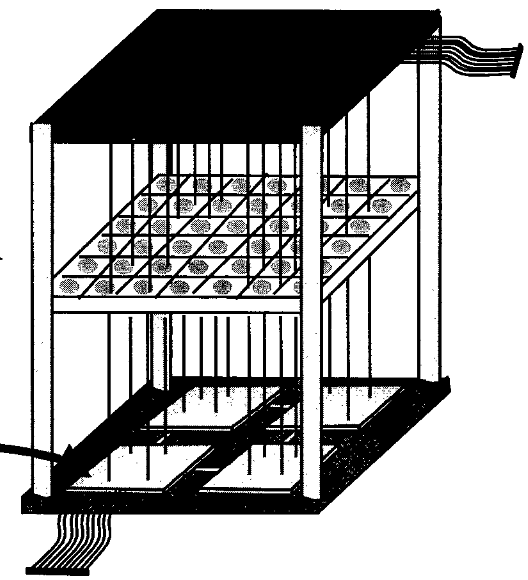
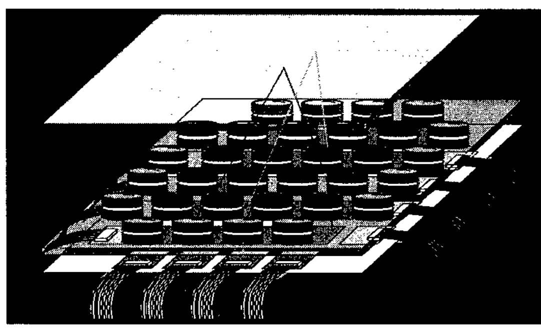
VLSI Photonics



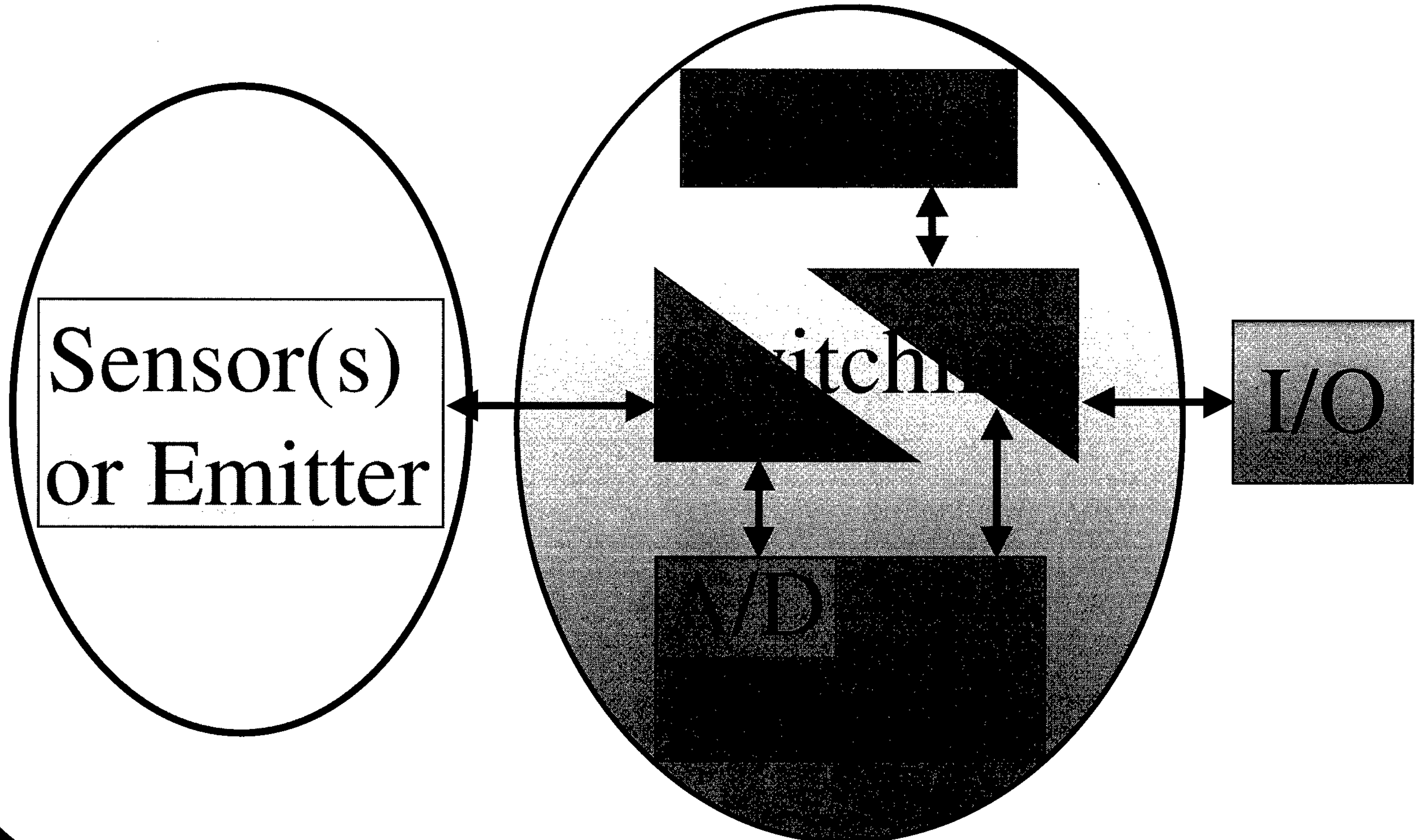
TBytes → of Information



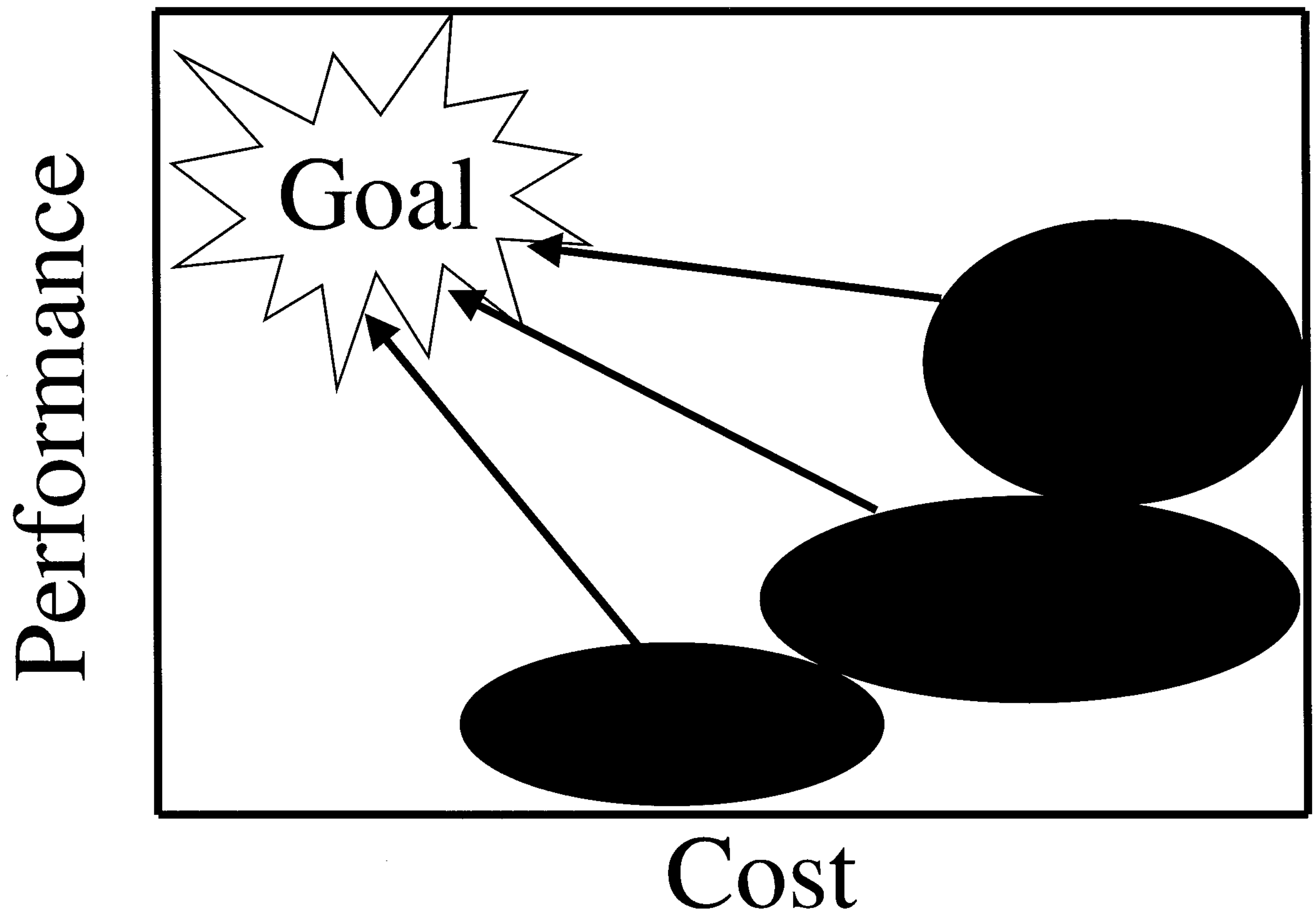


Chip-to-Chip Optical Interconnect

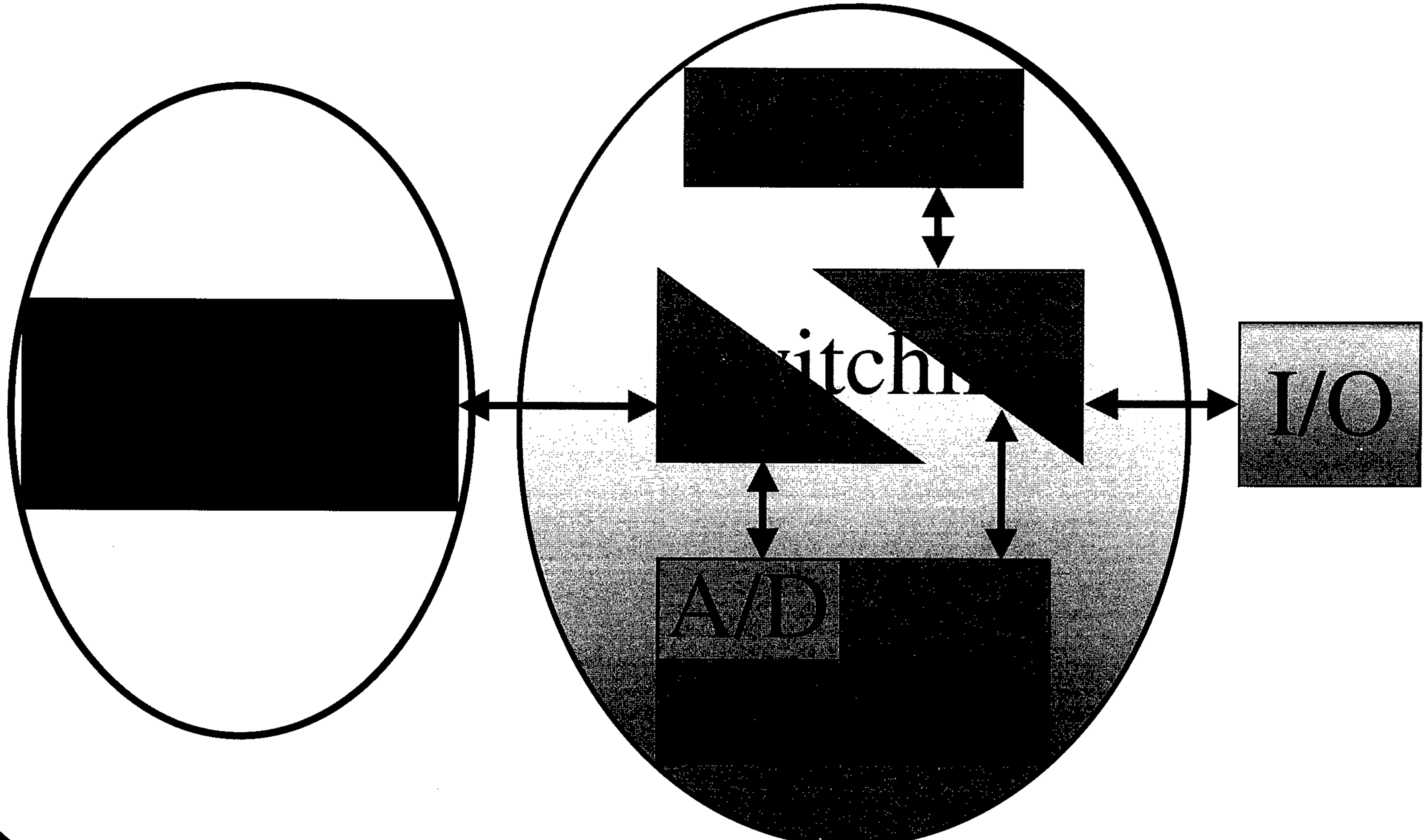
RF Photonics



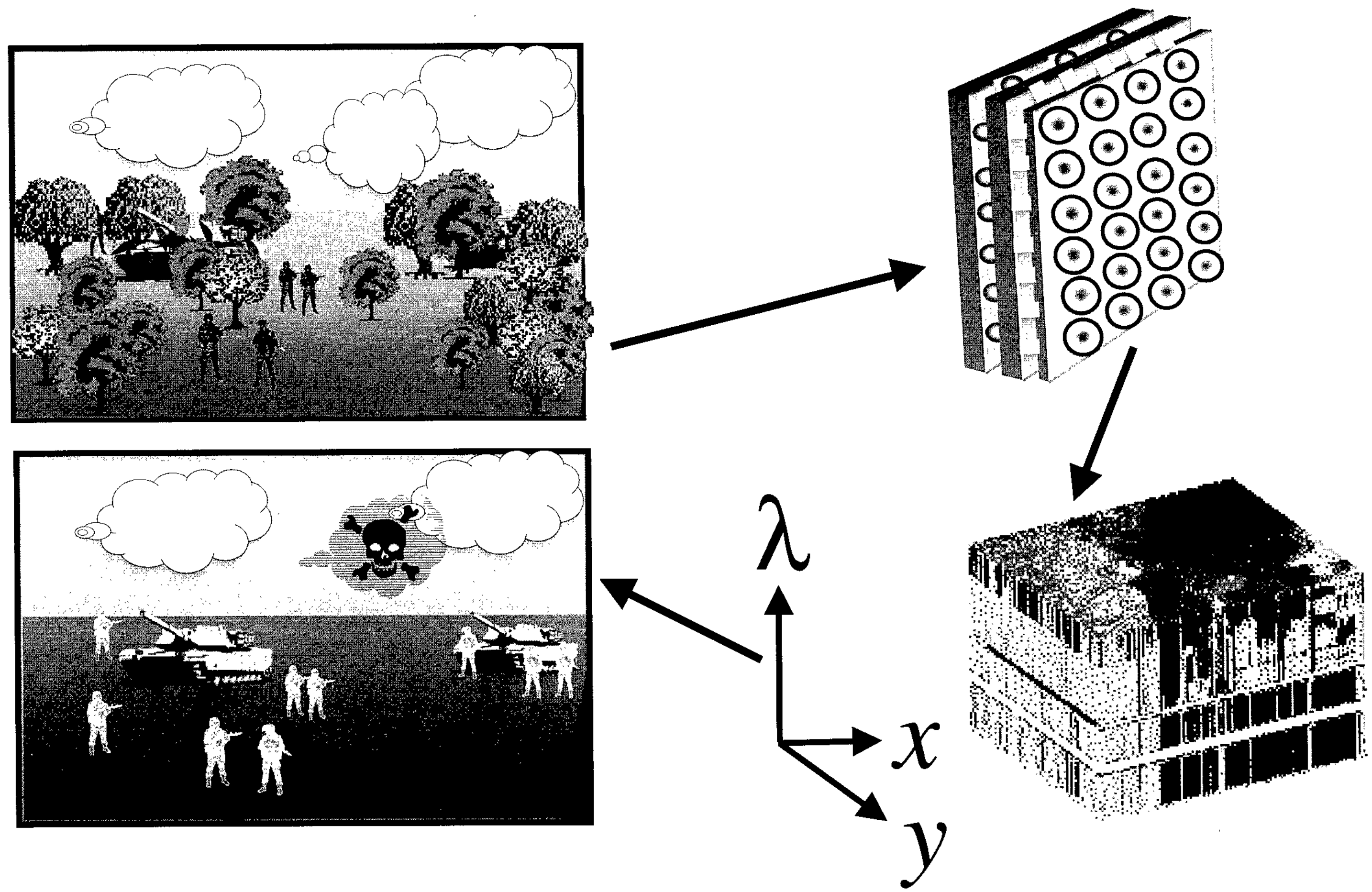
RF Photonics



Architecture

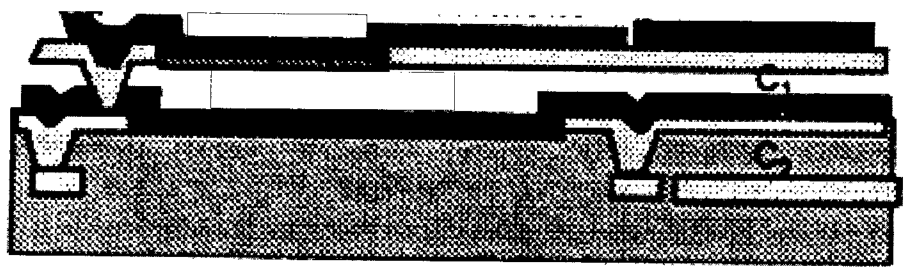


Integrated Sensors



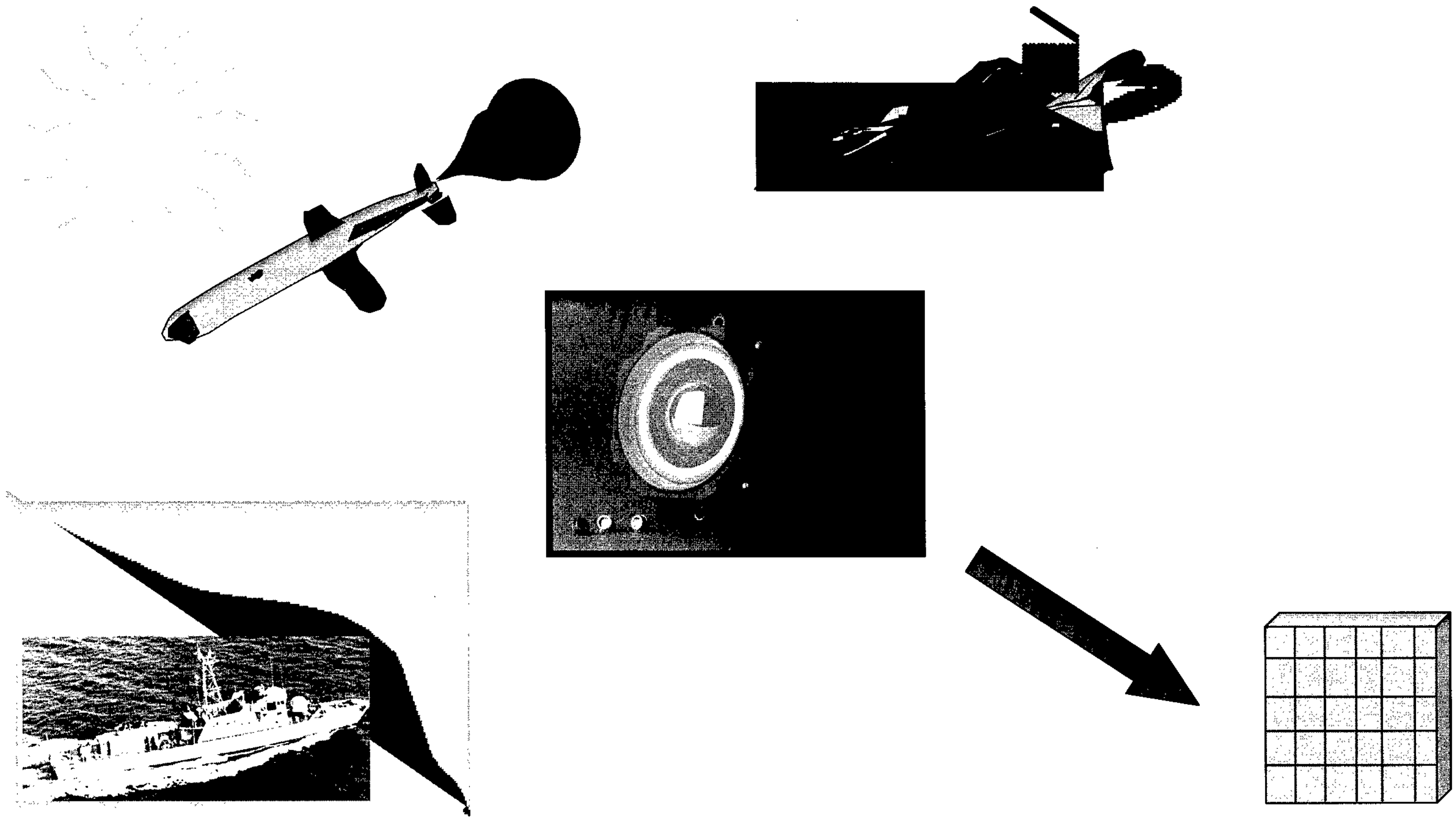
DARPA MTO

IR Sensitive Materials

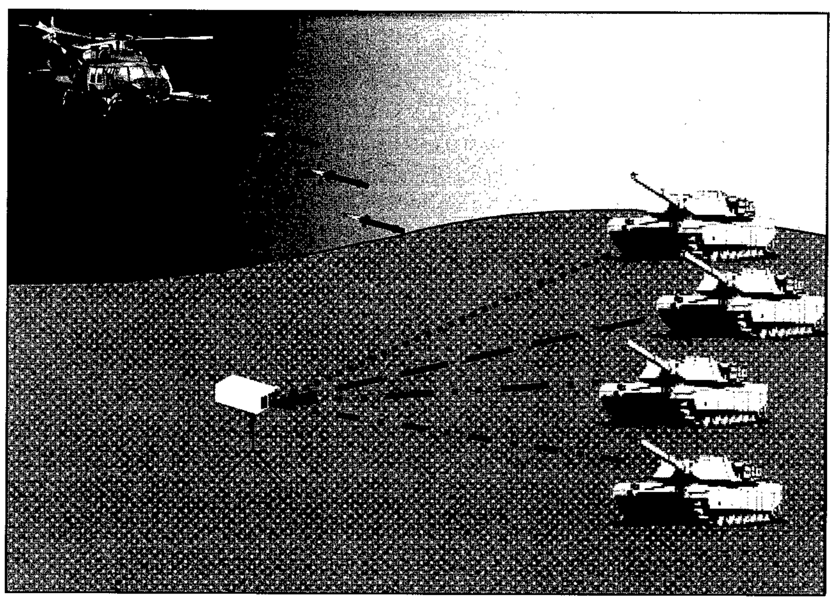


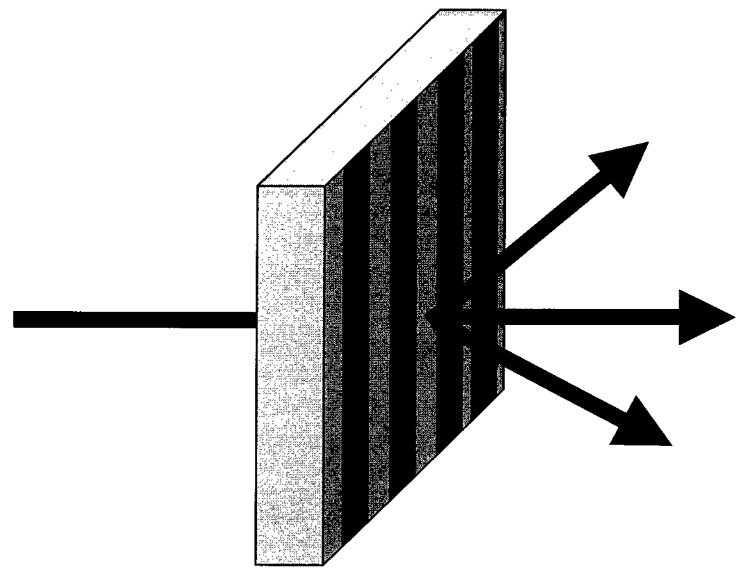
IR Sensitive Cantilever

Vehicle Self Protection



Steered Agile Beams





Multiple Target Engagements

DARPA

Photonics Overview

MTO

- MTO Applications Areas
- Technical Strategy: *Business Plan*
- [redacted]
- Future Opportunities

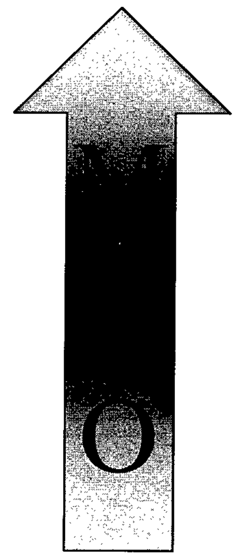
DARPA

Development Food Chain

MTO

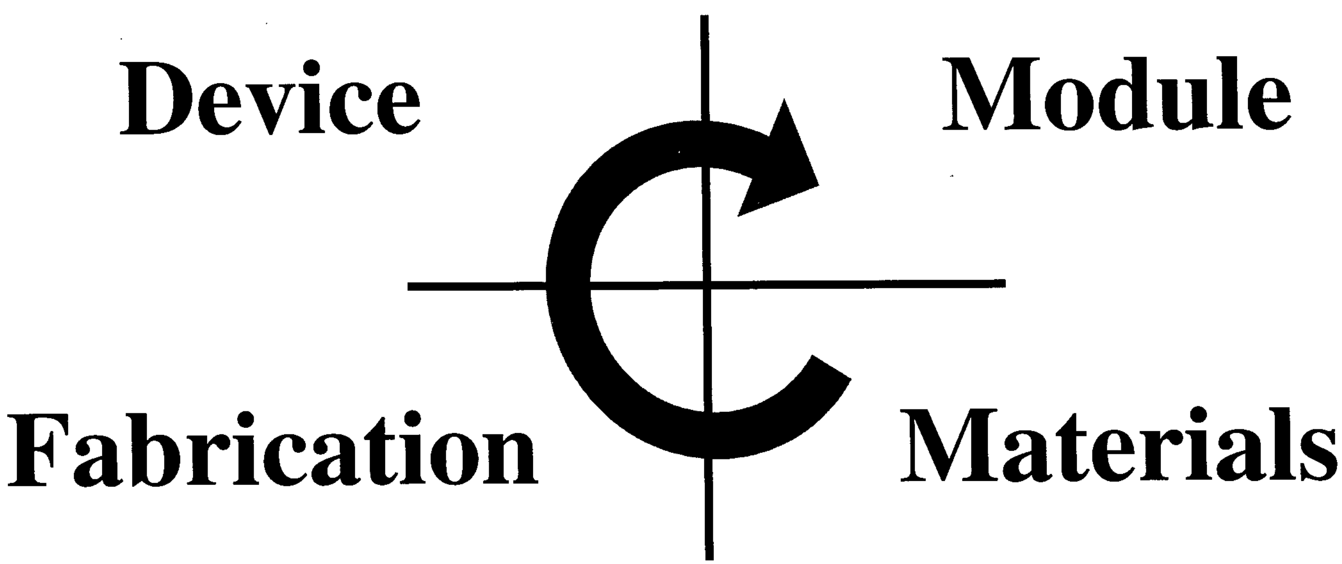
Applications
Systems
Subsystem
Module
Device
Fabrication
Materials
Science

Application Pull

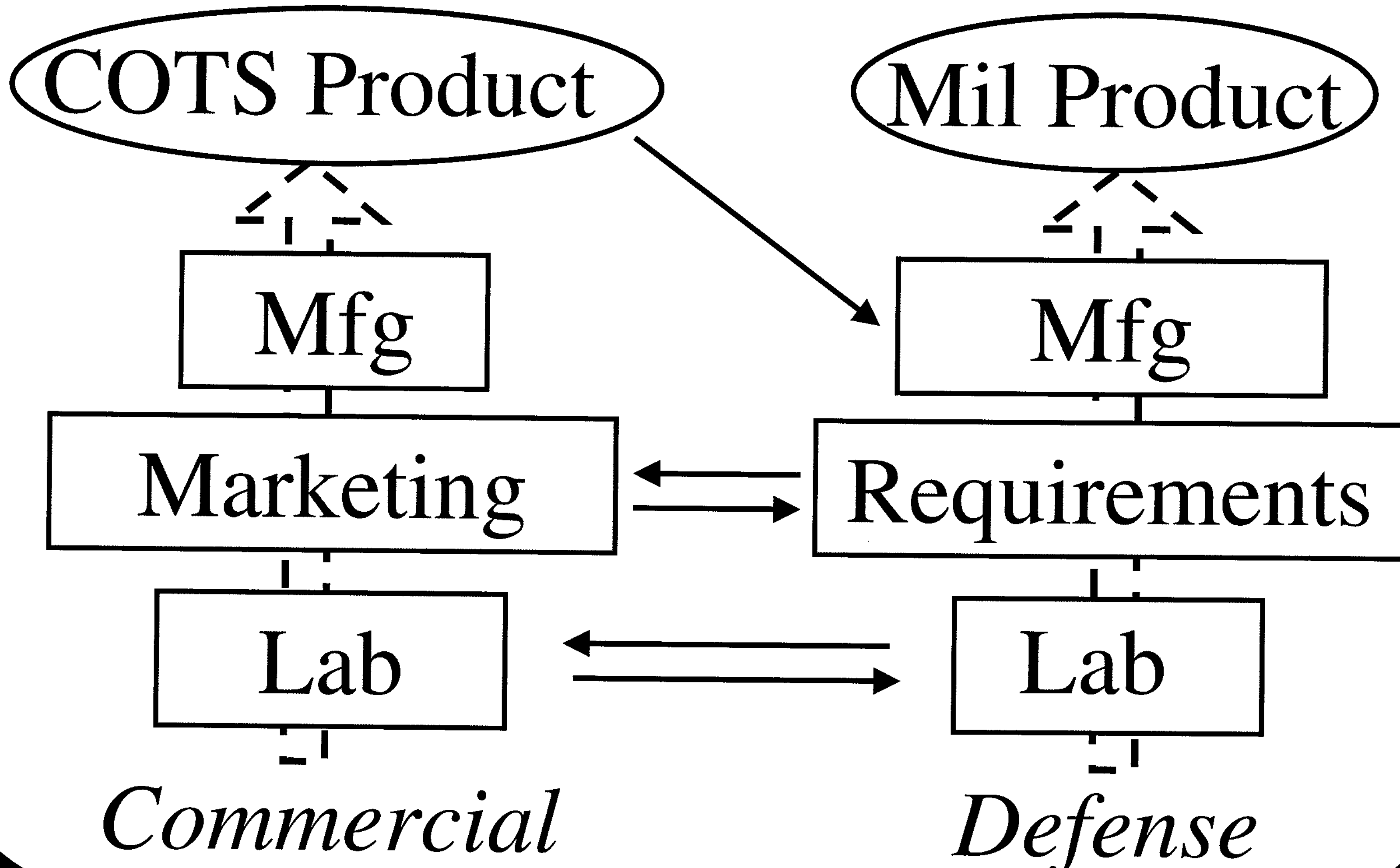


Technology Push

Development Cycle

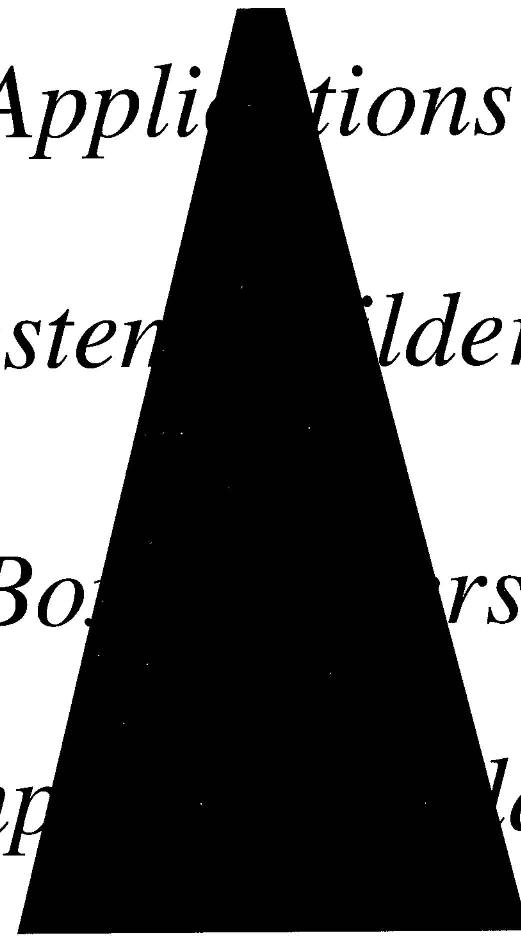


Com.-Def. Teaming



Funding Profile

Relative
Investment



DARPA

Photonics Overview

MTO

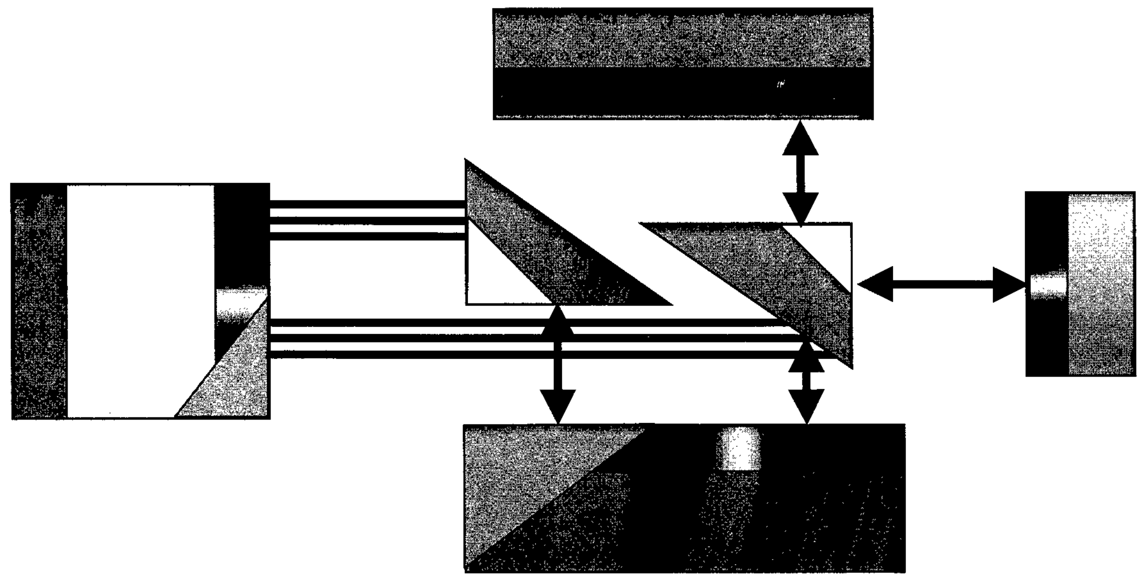
MTO Applications Areas

Technical Strategy: *Business Plan*

S&T Acquisition Strategy

[redacted]

Next Generation



Optical
- RAM
- Switching
- Processing

Multi-Spectral
Sensors
WDM Links

Displays

DARPATech 99

DARPA/MTO

Bruce Gnade

DARPA MTO

High Definition Systems

Objective: Develop leading-edge display technology to meet diverse, but specific, DoD needs. The goals include increased power efficiency, reduced weight and improved ruggedness, while pushing the state-of-the-art in display performance. Demonstrate DARPA-funded technology in military applications.

DARPA

High Definition Systems

MTO

- Current emphasis for HDS program
  - Accelerate the development of flexible, rugged displays (organic EL, zero-power reflective, self-assembled materials)
  - Push maturing technologies to demonstration phase (FED, Color EL)
  - Increase the demonstration of HDS supported technology (DMD, TFEL, plasma)

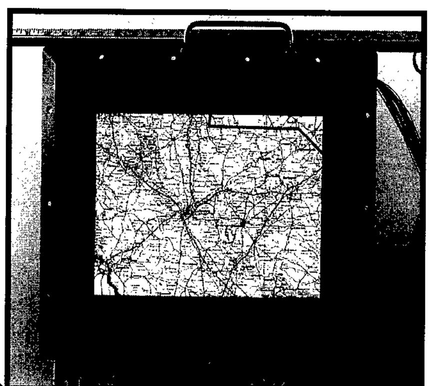
CLADS

PROBLEM: CRT display systems used in AWACS, JSTARS and ABCCC are becoming unsupportable:

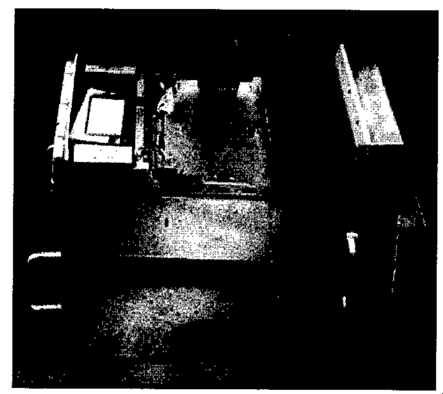
•Logistics Support: $208K/CRT, MTBF ~ 500 hours

SOLUTION : Technology independent systemTI-DMD, dpiX- AMLCD, Photonics - Plasma, etc.

Impact of FPD Technology:



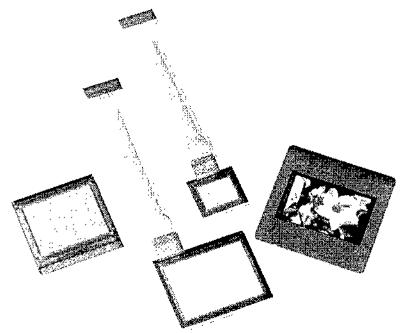
- -1064 lb..
- -1750 watts
- MTBF > 3300 hours
- +70% viewing area

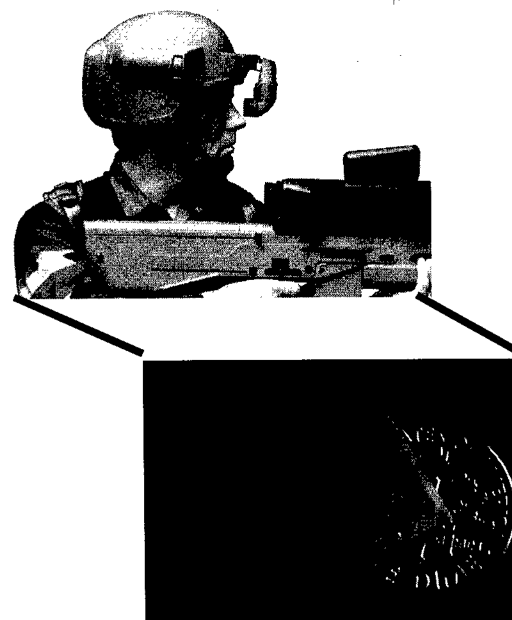


Small Image Sources

1280 x 1024
AMLCD for Comanche

640x480 AMEL
for Land Warrior





DARPA, SSCOM, CECOM-NVESD, ARL, USARARL, Armstrong Labs, NAWC

Kopin Corp, Planar Inc., Sarnoff Corp., Allied Signal, Thesys, UMC, MIT-LL, U of Fl, GTRI, GIT, Oregon Graduate Institute, Honeywell, Hughes, Kaiser

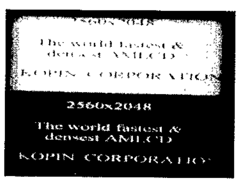
DARPA MTO

High Brightness Image Sources Rotocraft Avionics Systems

Performance goals
- **1280x1024**
- **1650 ft-L**
- **80:1 contrast ratio**
- **<1% reflectance**
- **Viewing angle +/-30°**

Joint development program
* DARPA
* Comanche
* Army
* NVESD

Proposed Technologies



AMLCD - Kopin

AMEL - Planar

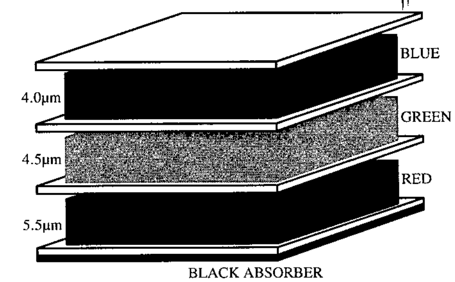
DARPA

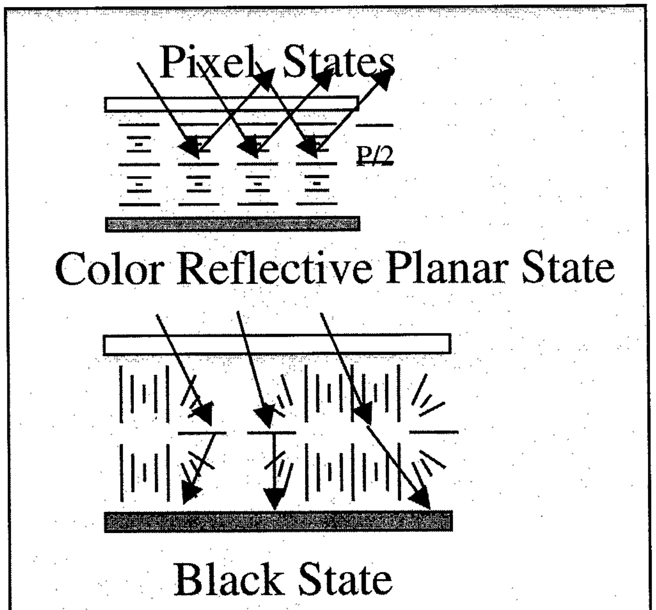
Zero-Power Displays

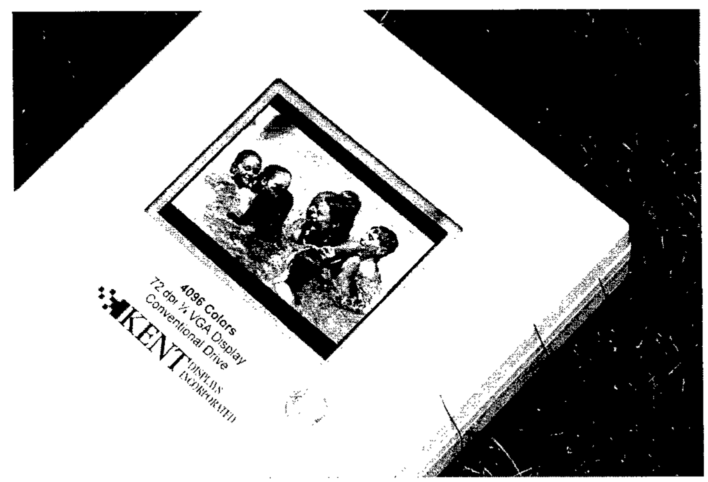
MTO

Advantages of cholesterics

1) Reflective in visible and IR
2) 2 AA batteries / year
3) Rugged plastic displays prevent breakage



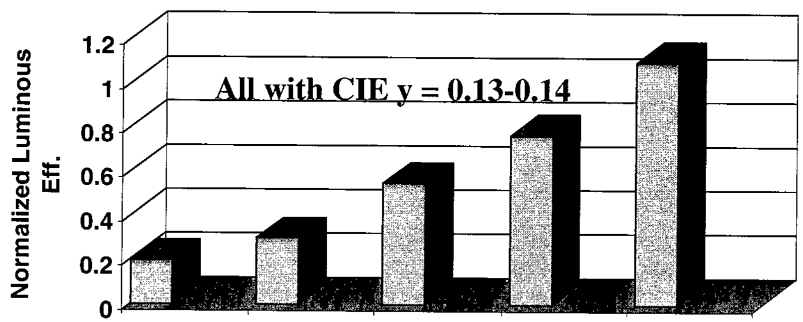


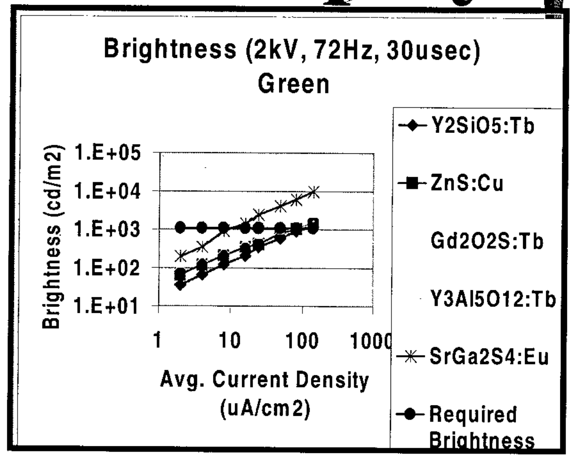


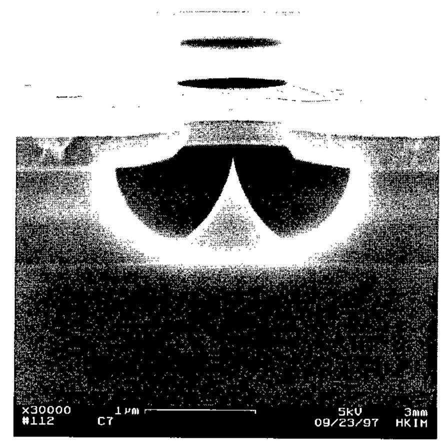
DARPA MTO

Materials for Emissive Displays

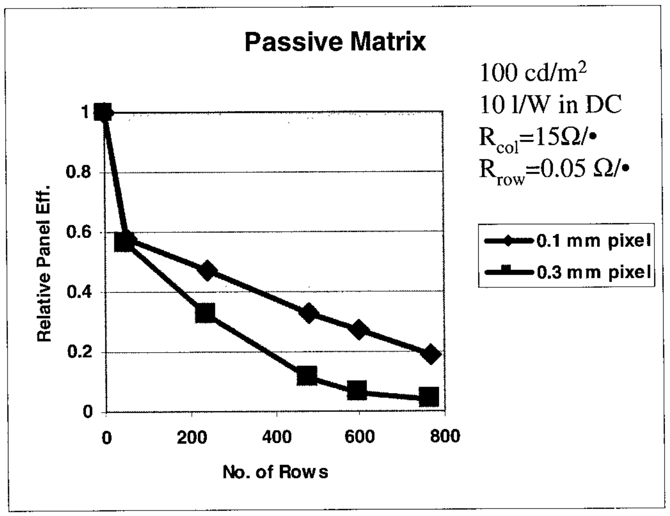
TFEL Phosphor Efficiency

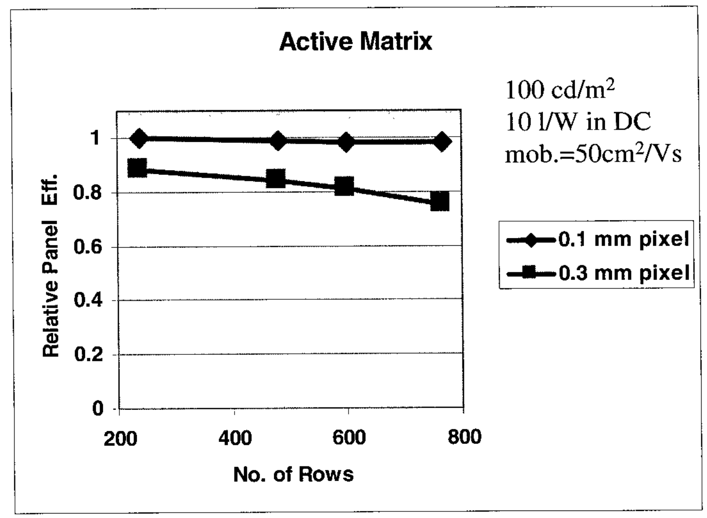






Active Matrix Backplanes on Flexible Substrates





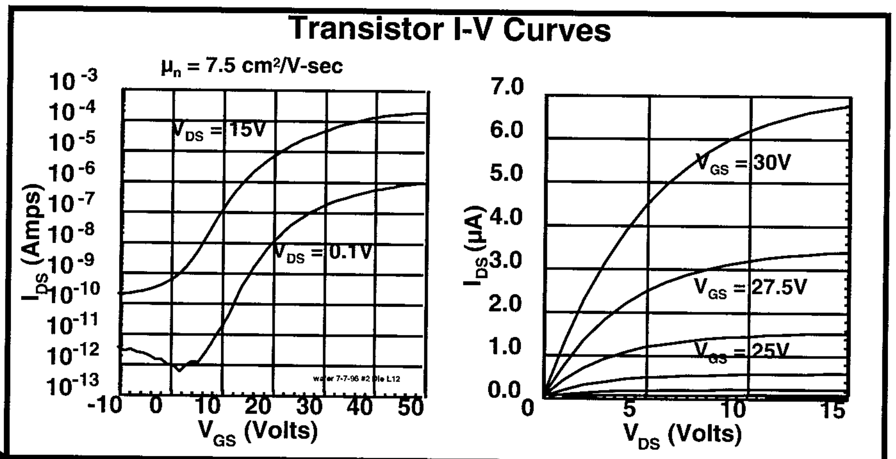
* Driving force for active matrix is power efficiency
* Pulsed operation and low duty cycle in PM require high current
* I^2R losses can reduce PM power efficiency by 25X

Provided by Jim Sturm - Princeton Univ. POEM

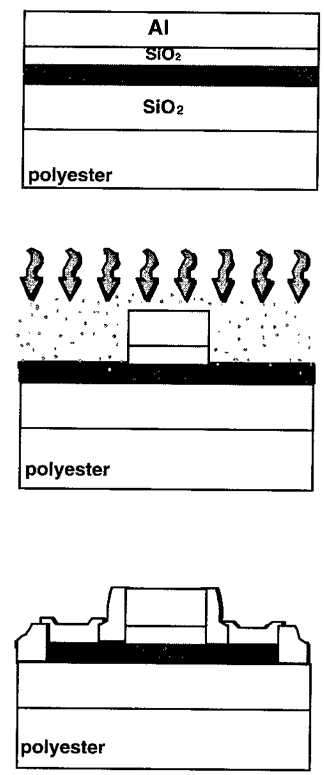
Poly-Si TFTs on Plastic

LLNL

* Substrate = Polyester
* Max. Processing Temp = 100°C
* Max. Anneal Temp. = 150°C
* Si Crystallization ⇒ 308nm XeCl Excimer Laser

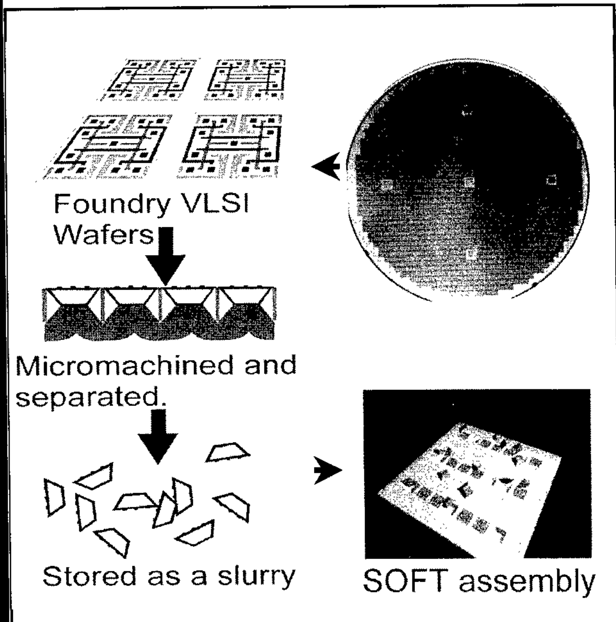


Transistor Process Flow



Self Orienting, Fluidic Transport

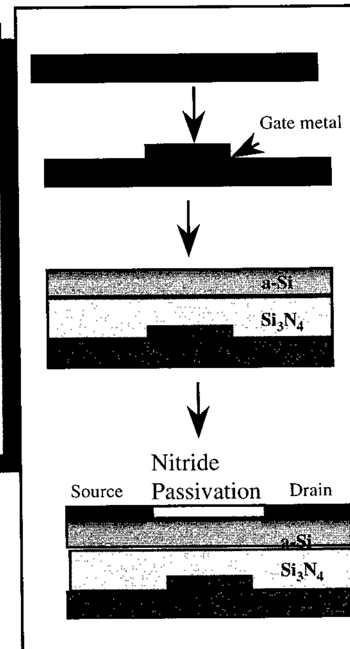
SOFT process Flow



SOFT Advantages

1) high performance electronics
2) technology independent
3) size independent
4) low temp. processing
5) low capital investment
6) 2x10^7 pixels/8" wafer

TFT process Flow

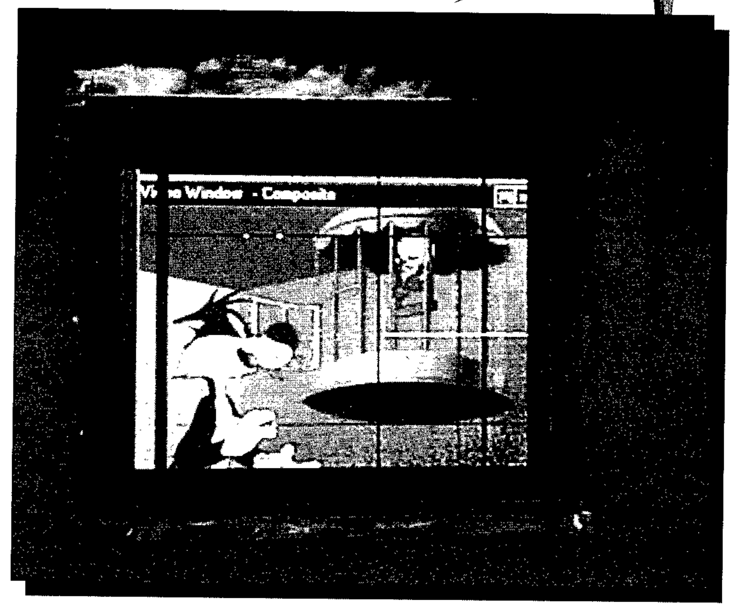


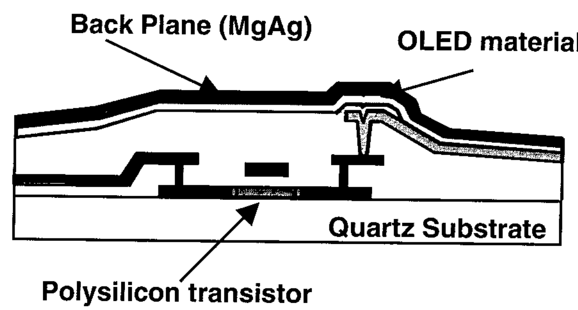
Beckman Display

Display Process

Active Matrix Organic LED

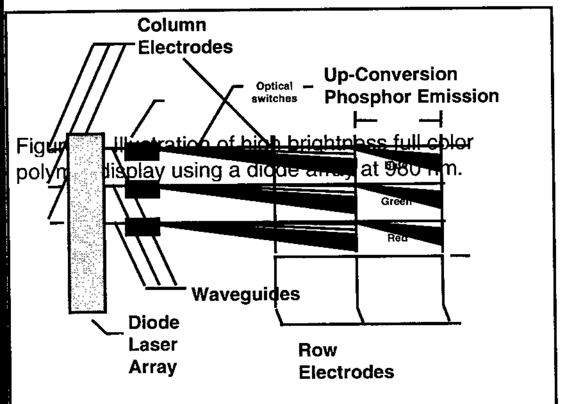
Green: (Alq_3)
Luminance: 850 nits
Polysilicon





Planar Systems
Eastman Kodak
Sarnoff Corp
Princeton University

Polymer Switched Matrix Display



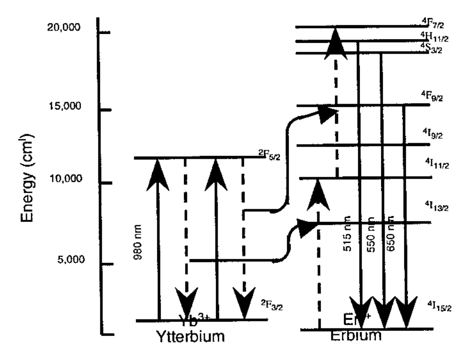
Optical IC

1.) Low Power

2.) Large

3.) Flexible

4.) Optical toolkit



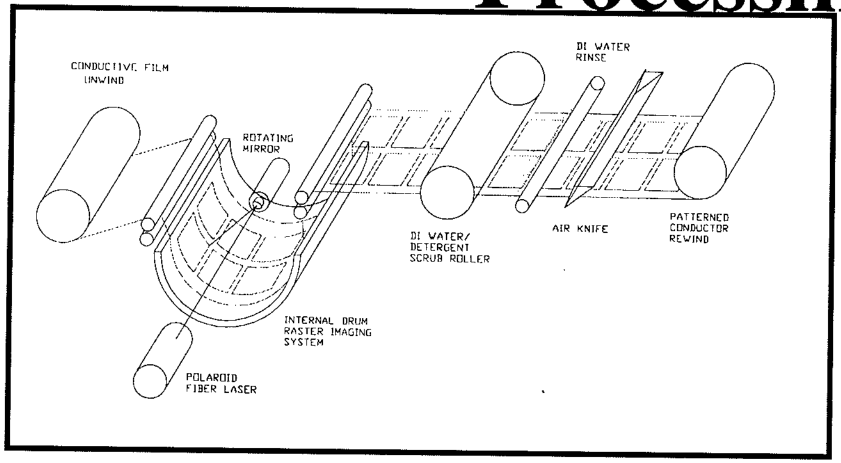
Up-Conversion Phosphors

Gemfire

DARPA

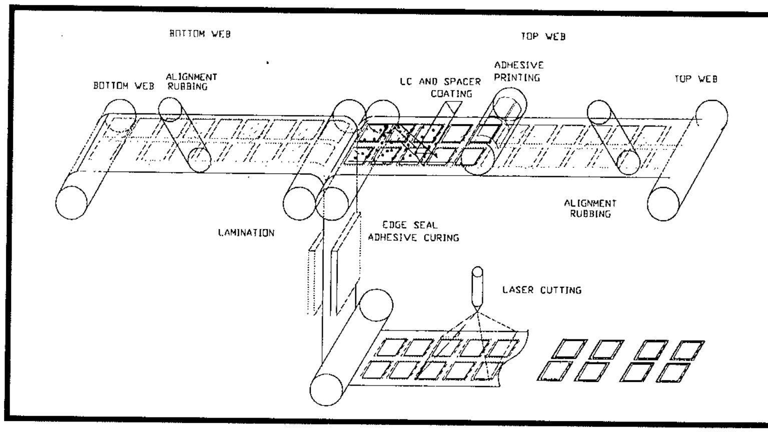
Roll-to-Roll Display Processing

MTO



Roll-to-Roll laser etching electrode patterning

Roll-to-Roll display assembly

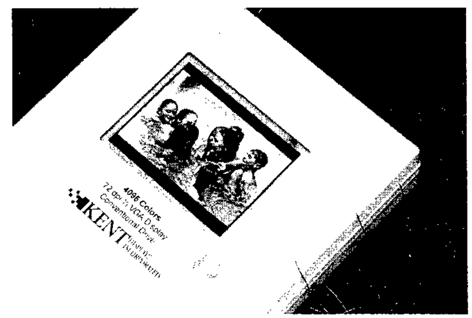


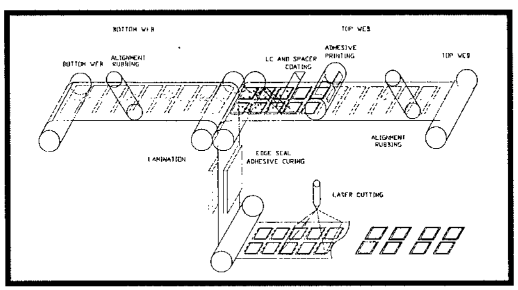
Polaroid

Summary

What do we want in displays?

* Low power
* Rugged
* Sunlight readable
* Interactive
* Inexpensive





Advanced Imaging Sensors

Uncooled Infrared

Three Dimensional Imaging

DARPA Tech ‘99

Raymond Balcerak
Microsystems Technology Office

DARPA

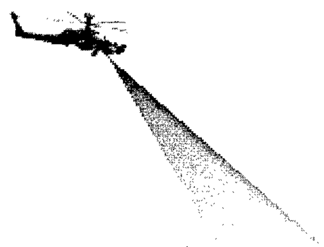
Imaging Systems

MTO

DoD Requirements

- Long Range Targeting
- Target Identification
- Precision Strike
- Damage Assessment
- Sensor Matched to the Vehicle
  - Robotics
  - Micro-air Vehicles

Need for Precision Targeting



Wide Area Search

Rapid Target Selection

DARPA

MTO

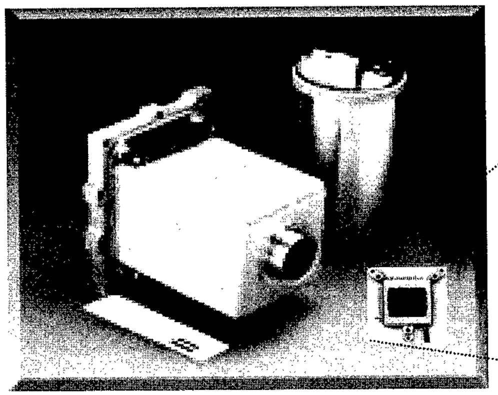
Advanced Imaging Sensors

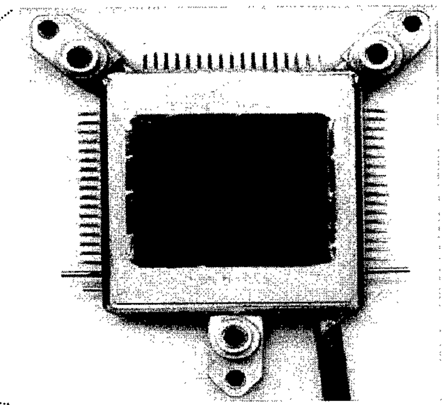
<u>Objectives:</u>

- Transform Most of IR Imaging from Cooled to Uncooled

- Add Precision Targeting
  - Short Wave IR
  - 3-D Imaging

Why Uncooled IR?





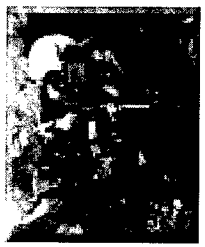
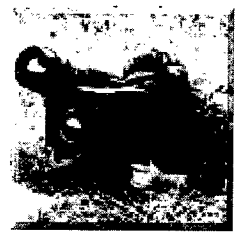
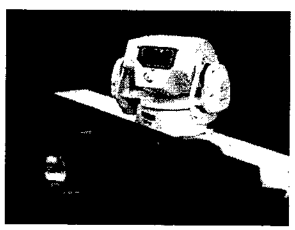
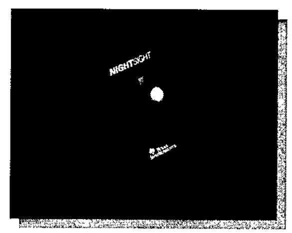
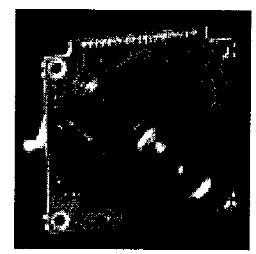
Cryogenic Sensor   Uncooled Flat Pack

- 20 x Power Reduction
- 10 x to 100 x Size Reduction
- 10 x Cost Reduction

DARPA MTO

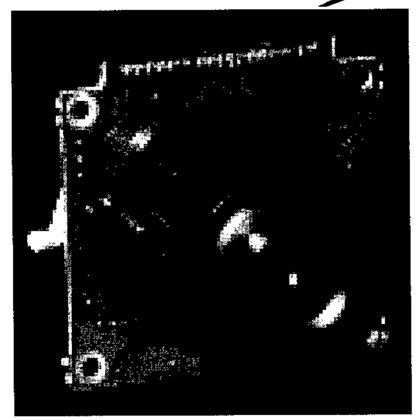
Uncooled IR Applications

3-10X

Current	Emerging	Future
		
Rifle Sight	Missile Seeker	Target Acq.
		
Viewer	Unattended	Micro Sensor

1X — *Performance* — *20-70X*

Uncooled IR Payoff



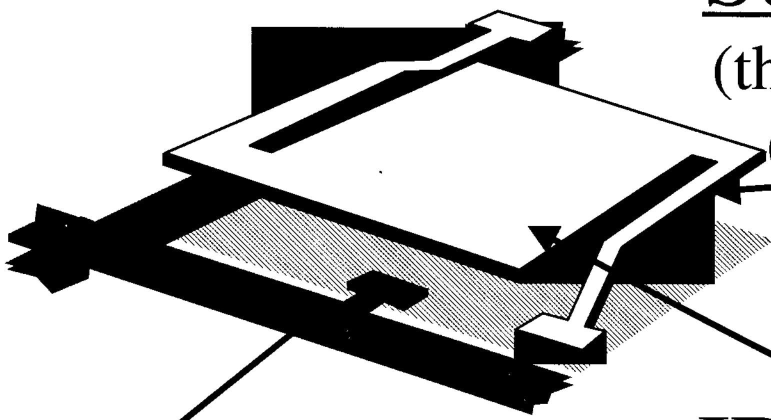
Missile Seeker

- Targeting Through the Missile
  - –15 lbs. Weight Savings
- 7x Cost Reduction

U-Sensor

- Low Weight
  - – 5-50 Grams
- Sensors for Novel Applications

Current Uncooled Detector



Support Arms
(thermal signal loss)
(micro-structure support)

Electronic Read-out
(low noise amplifier)
(high density unit cell)

IR Material
(optical absorption)
(one-over-f noise)

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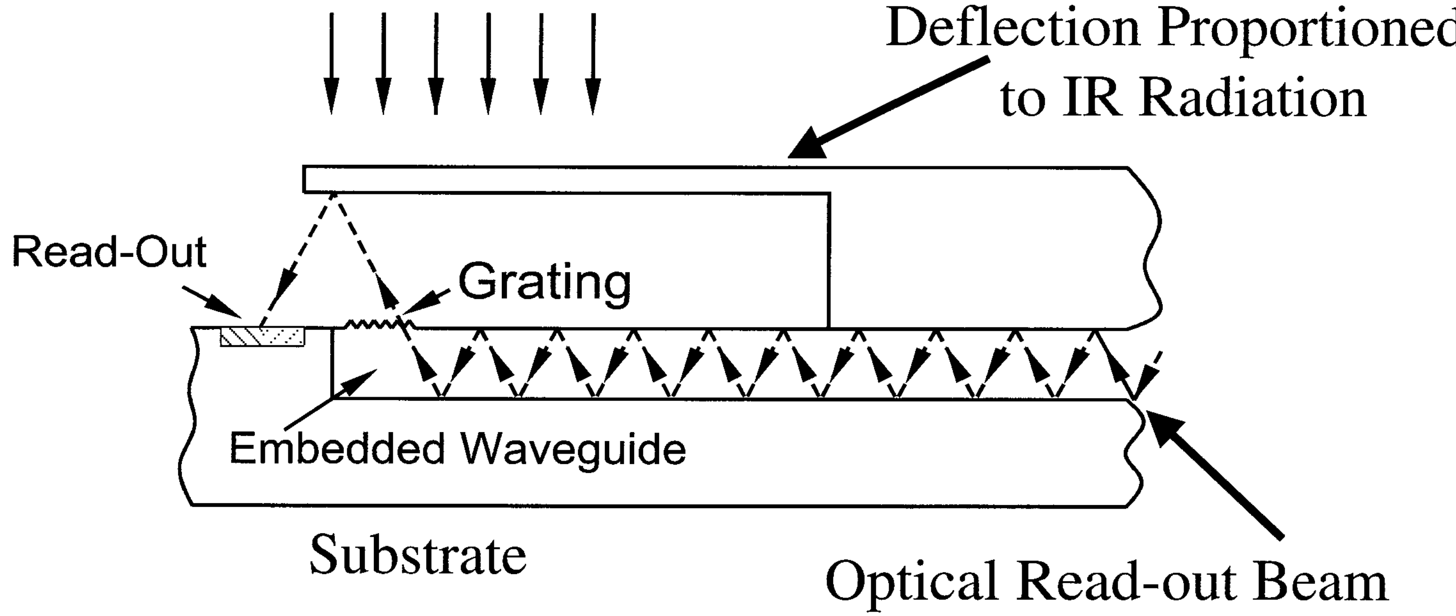
Thermal Detector Challenges

MTO

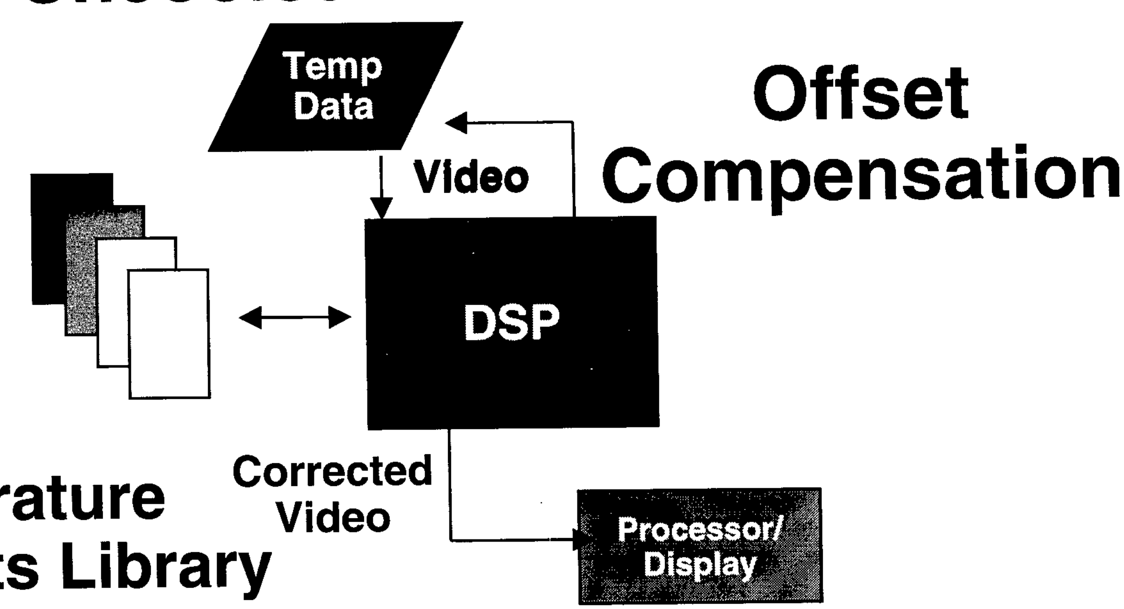
- Ideal Thermal Isolation
- Optical Absorption in Thin Layer
- Thermal Time Constant
- Non-Contact Read-out
- Electronic Compensation
- Array Technology

Ideal Thermal Device
Concept



<u>Thermal Sensitive Pixel</u>

Uncooled IR Camera System



Electronic Temperature Compensation Approach

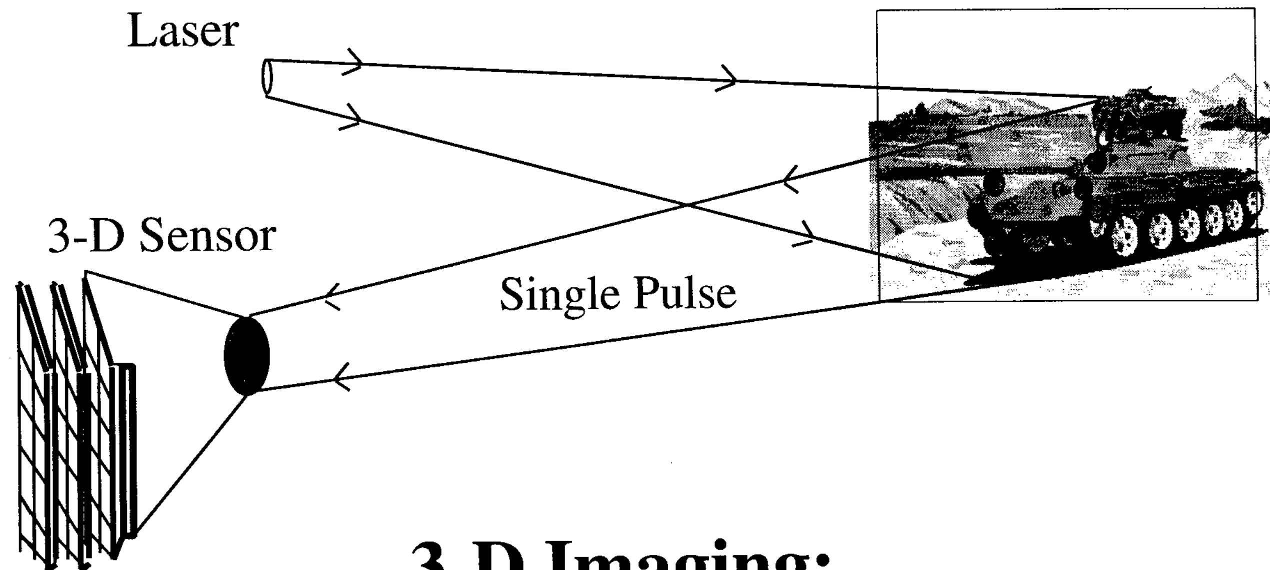
DARPA

Signal Processing

MTO

- Temperature Compensation
  - Milli-Degree Accuracy
  - Coefficient Library
- Large Dynamic Range
  - On-Chip Correction/Anti-Blooming
  - Local Contrast Enhancement
  - Linearity Over Scene Temperatures

Precision Targeting



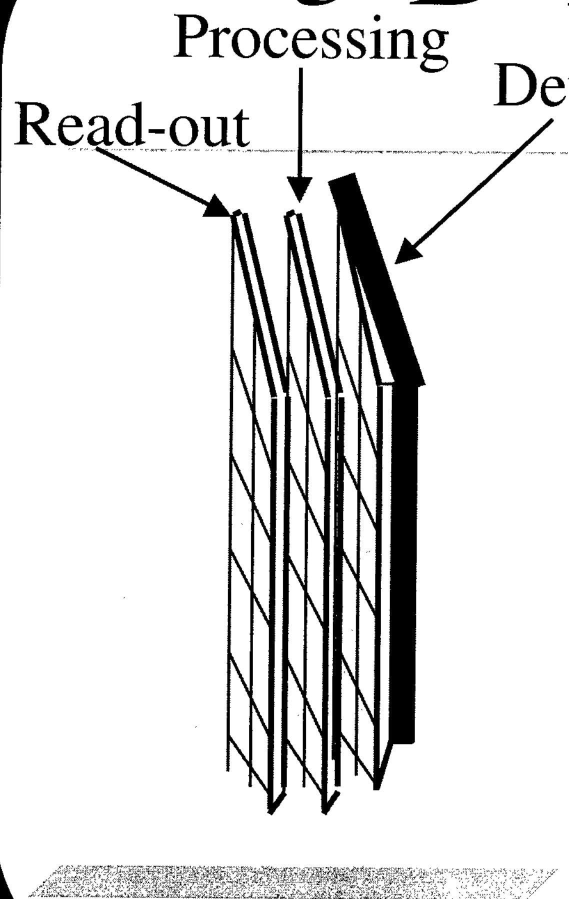
3-D Imaging:

- Adds Pixels on Target
- Aspect Invariant
- Wave Length Flexibility
- Camouflage Penetration
- Minimum Platform Stabilization

DARPA

3-D Technology

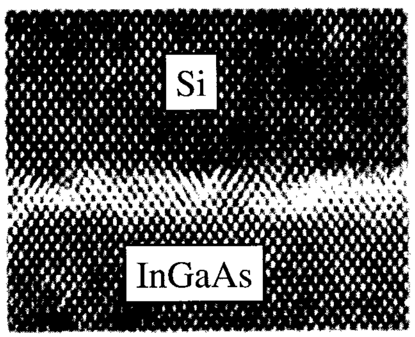
MTO



Challenges

- SWIR Detection with Internal Gain
- High Quantum Efficiency
- High Speed (Gigahertz) Imaging Sampling
- Low Noise Pre-amp.
- Output Format (A/Ds)
- Gain/Bias Control Feedback

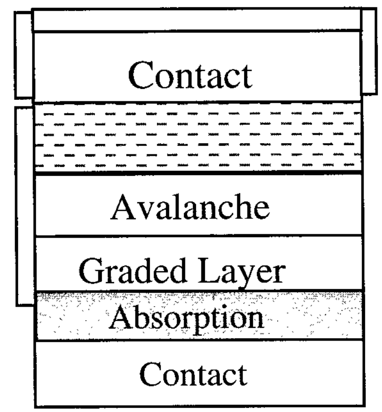
High Speed Devices with Gain-concepts



Wafer Fusion Bonding

Gain

Sensing



Grown Structure

[redacted]

Summary

- Uncooled IR Dramatically Expands Applications
- Ten Times Performance Increase Necessary for Uncooled IR
- Precision Targeting with Unique 3-D Imaging Devices

DARPA

Distributed Robotics MTO

Program Managers

Mr. Ellison Urban (MTO)

Dr. Regina Dugan (ATO)

Technical Support

Dr. Elana Ethridge (SPC)

DARPATech 99

DARPA **Distributed Robotics** MTO

The average rat can:

- wriggle through a hole no larger than a quarter
- scale a brick wall as though it had rungs
- swim half a mile and tread water for three days
- gnaw through lead pipes and cinder blocks with chisel teeth that exert 24,000 lbs. per square inch
- survive being flushed down a toilet and enter buildings by the same route
- plummet five stories to the ground and scurry off unharmed
- multiply so rapidly that a pair could have 15,000 descendents in a year's life span*

*It is not anticipated that this goal will be met by the DARPA program.

National Geographic July 1977

DARPA

Distributed Robotics

MTO

Develop

small robots (less than 5 cm)

Using

novel integrated small system design techniques

For

application in military missions

DARPA

Distributed Robotics

MTO

Challenges:

- Non-linear scaling laws
- Mobility innovation
- Small system integration
- Interface of micro and meso scale technologies to the real world
- Energy constrained environments
- Multi-robot control strategies
- User interfaces

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Distributed Robotics MTO

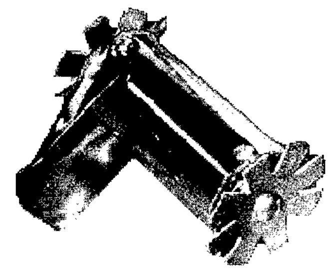
Current Projects

- Carnegie Mellon University
- Case Western Reserve University
- Caltech
- University of Minnesota
- Northwestern University
- UCLA
- North Carolina State University
- Duke University
- Xerox PARC
- University of Michigan
- Michigan State University
- Sandia National Laboratory
- USC/ISI

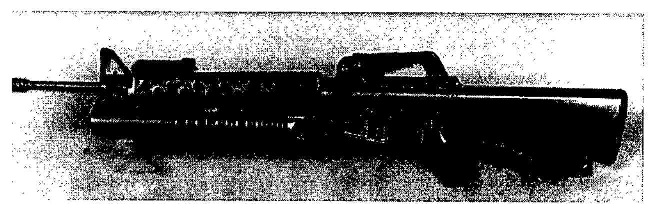
DARPA

Distributed Robotics

MTO



- 40 mm diameter robot
- Includes MEMS chemical sensor, MEMS vibrational device and video camera
- Robot rolls and/or jumps up to 1 meter
- Can be thrown or shot from M203 or larger robot
- Enter building (through window)
- Locate chemical (gas)
- Locate vibration source
- Locate people



University of Minnesota

DARPA

Distributed Robotics

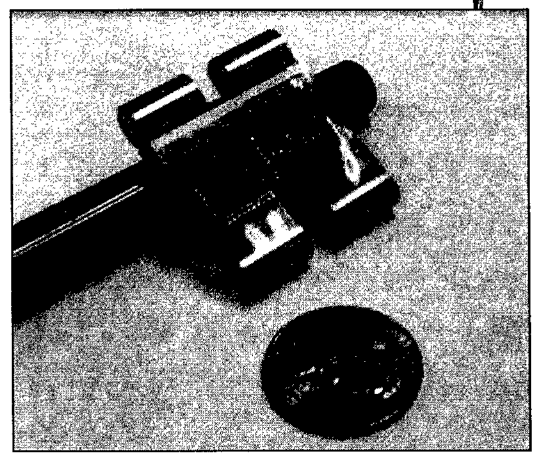
- Small intelligent robot appx 1 cubic inch
- Integrated system with chem-resistor/humidity sensor, RF communications, covert design
- Distributed/decentralized algorithms

-Simple individual algorithms with sophisticated collective behavior/ processing

-Physically distributed memory

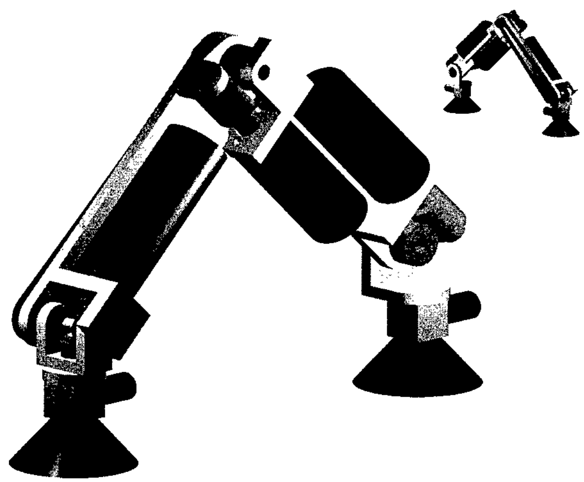
-Inherent parallel processing

-Time-spatial correlation



Microcrawler

Distributed Robotics

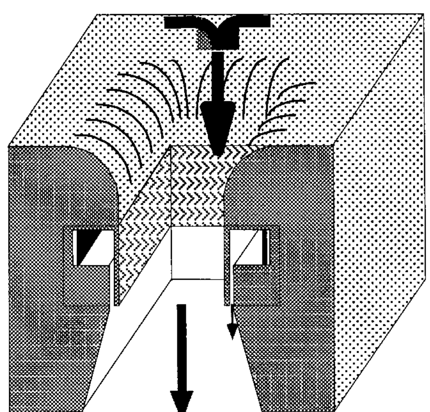


- Inch worm design
- Suction cups with micro-pumps for locomotion
- Climbs glass or other smooth surfaces
- Camera in suction cup
- Radio
- Building surveillance mission

Michigan State University

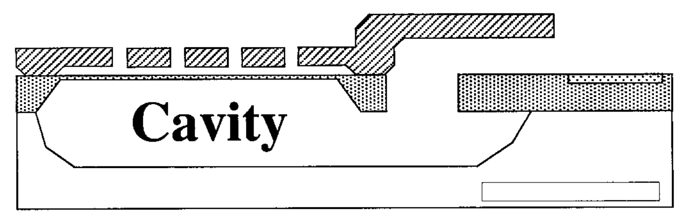
Distributed Robotics

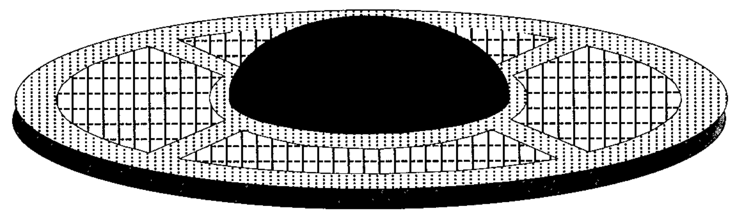
Flying Silicon



Acoustic Ejector

Helmholtz Resonator





Micro Air Platform

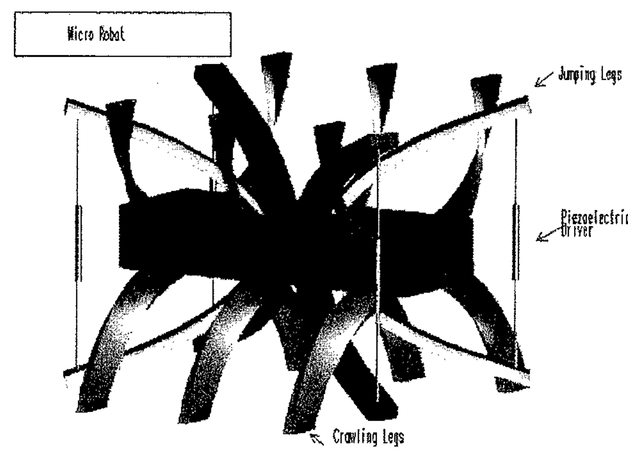
University of Michigan

Distributed Robotics

Simple jumping robot based on a single actuator
Pneumatic "jumper" + positioning legs

Miniature control module including:

- -RF range finder for simple location detection
- -Magnetic compass
- -Charge pump PZT control circuit
- -Microcontroller

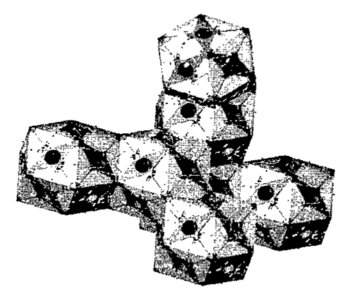


North Carolina State University

Distributed Robotics

- Large scale integration of miniaturized components
- Robust distributed control
- Modular locomotion/ application strategies
- Reconfiguration planning

Spider



Dodecahedron

Xerox PARC

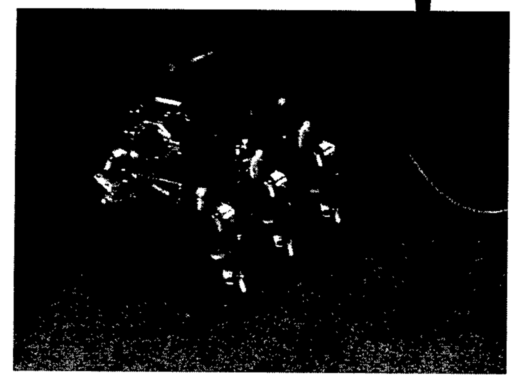
DARPA

Distributed Robotics

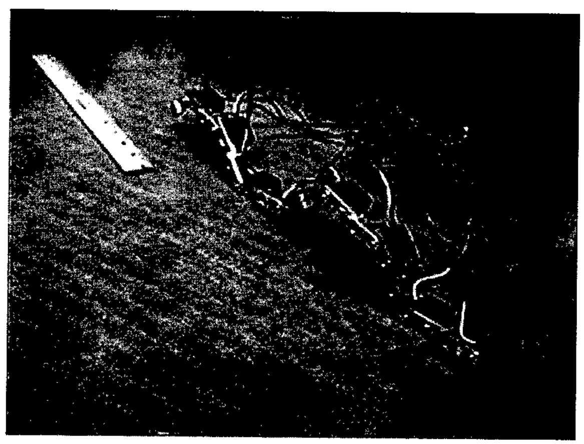
MTO

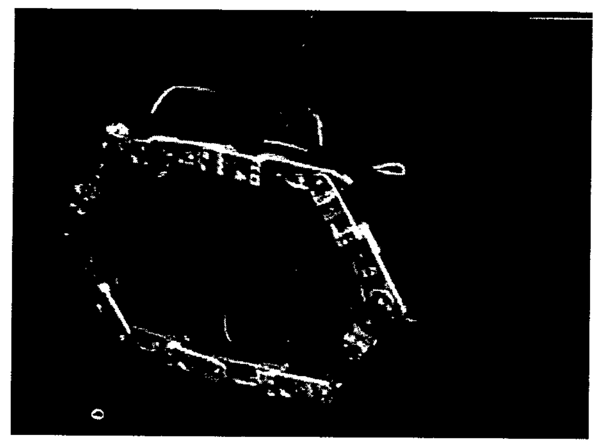
Configurable Robots

- Modular construction
- Sensors, camera, communications
- Reconfigurable



Hexapod





USC/ISI

Distributed Robotics MTO

Aquatic MicroHunters track a signal in 3D to its source:

Signals can be any vector field:

- **EM fields, including earth's magnetic field**
- **acoustic fields**
- **pressure gradient (*e.g.* depth in water column)**
- **light**

MicroHunters characteristics:

- **extremely simple**
- **can be very small (work at MEMS scales)**
- **few, miniature components**
- **few moving parts**
- **robust (can use low-grade signals, can survive damage)**

Distributed Robotics

New BAA will be issued in August 1999

- Novel miniature robots
- Integrated microsystems that move
- Collaborative robots
- Mission specific applications

MEMS 2003 and Beyond

A DARPA Vision of the Future of MEMS

Albert P. Pisano, Ph. D.

MEMS Program Manager
Microsystems Technology Office
Defense Advanced Research Projects Agency

(703) 696-2278
apisano@darpa.mil
http://www.darpa.mil/MTO/MEMS/

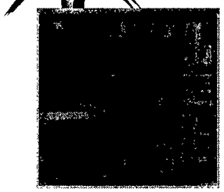
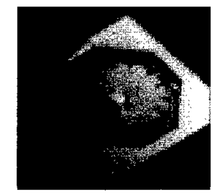
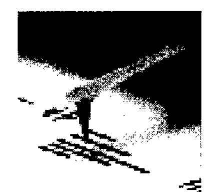
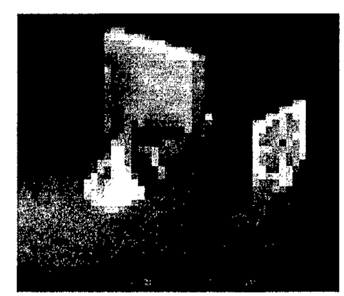
What Are MEMS?

- A way of making things
  - Leveraging on existing infrastructure of IC fabrication tools
  - Prototype on the exact mass-production fabrication tools
- Co-location of sense, compute, actuate, control, communicate, power
  - Increase performance and decrease cost
  - Integrate an increased number of fabrication technologies
- Closed-loop, microscale control of electrical, thermal, fluid, magnetic, optical, and mass flux
  - MEMS is a surface technology
  - Control phenomena on the microscale
  - Cause large effects both on macroscale and microscale

What Are MEMS?

- High spatial resolution and high temporal bandwidth
  - Integrated solutions offer greater physical density
  - Miniaturized components offer faster response
- MEMS at both microscale and macroscale
  - Large array of MEMS on a chip
  - Large array of MEMS "islands" on a macro platform
  - Dual-scale interconnect problem (integration required)
- The relevant size metric is the minimum feature size
  - Overall device or system size is irrelevant
  - Minimum feature size determines the required technology
- MEMS as Analog of Transistors
  - Direct and/or control power from macro and other sources

Defense Applications of MEMS

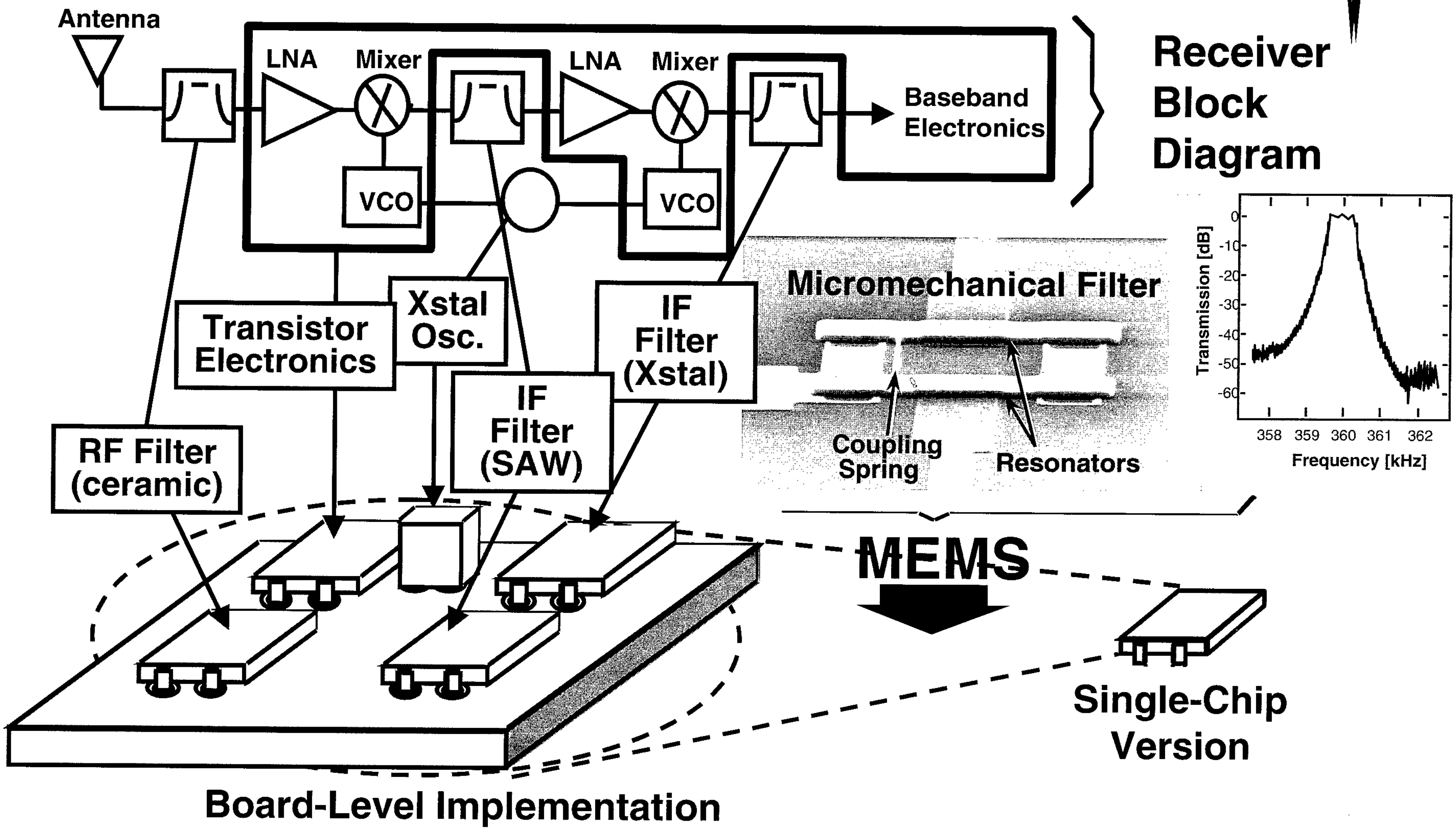
- <u>Inertial navigation</u> units on a chip for munitions guidance and personal navigation 
- <u>Electromechanical signal processing</u> for ultra-small, ultra low-power wireless communication 
- <u>Distributed unattended sensors</u> for asset tracking, environmental monitoring, security surveillance
- <u>Integrated fluidic systems</u> for miniature analytical instruments, propellant and combustion control 
- <u>Weapons safing, arming and fuzing</u>
- <u>Embedded sensors</u> and actuators for condition-based maintenance 
- <u>Mass data storage</u> devices for high density, low power
- <u>Integrated micro-optomechanical components</u> for identify-friend-or-foe systems, displays and fiber-optic switches 
- <u>Active, conformable surfaces</u> for distributed aerodynamic control of aircraft and adaptive optics

What is the Future of MEMS?

MEMS is an enabling technology that will be part of both macro and micro systems.

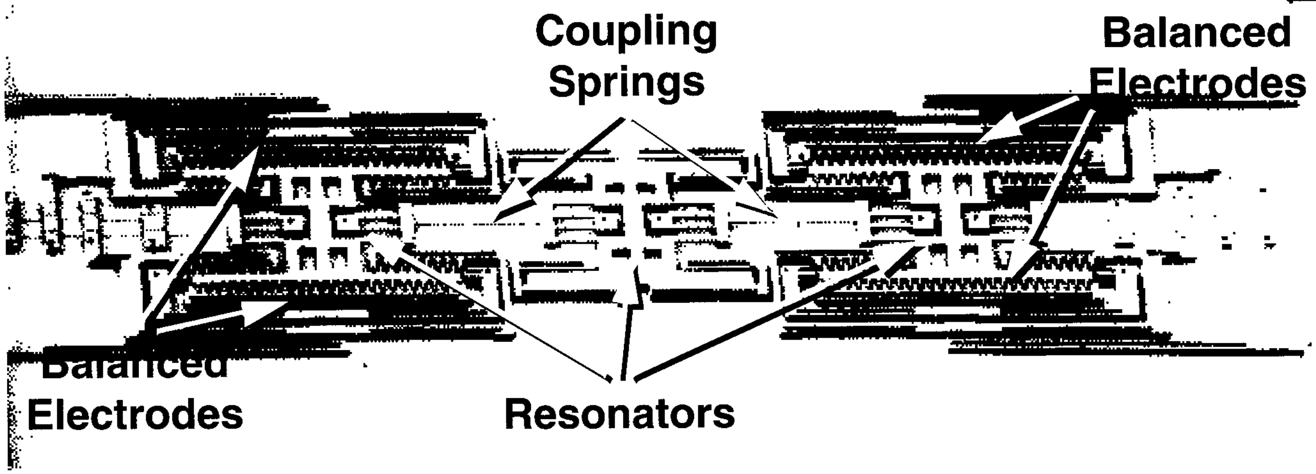
- Wrist Communicator
- Robust Jet Engine
- Stand-Off Chemical Sensing
- Micro Airborne Sensor/Communicator
- Micro Thermal-Chemical Power Systems

Wrist Communicator

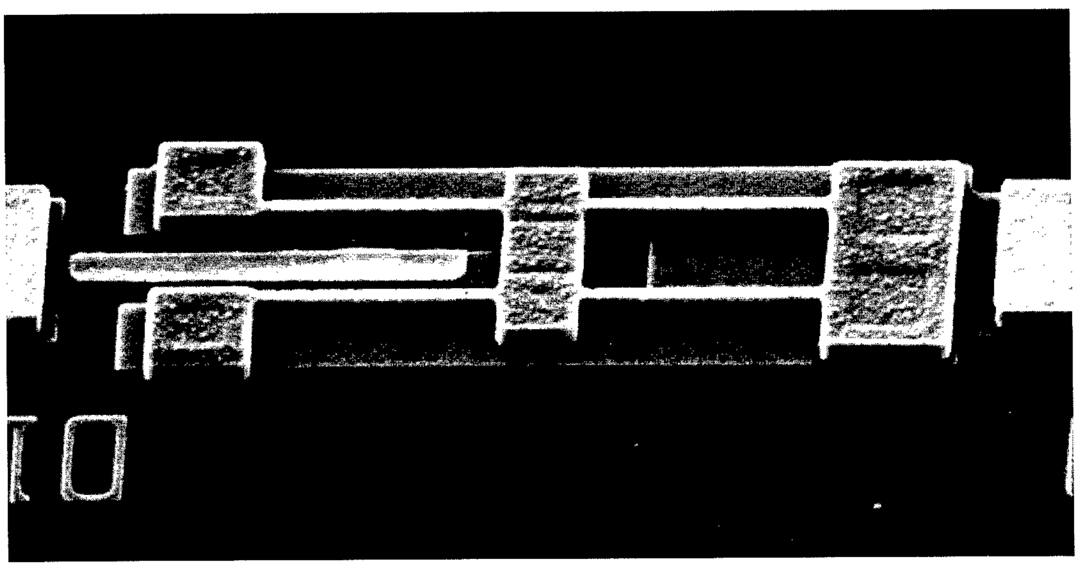


Univ. of Michigan
MEMS for Signal Processing

Wrist Communicator



Sixth-Order Bandpass Filter with Audio Center Frequency

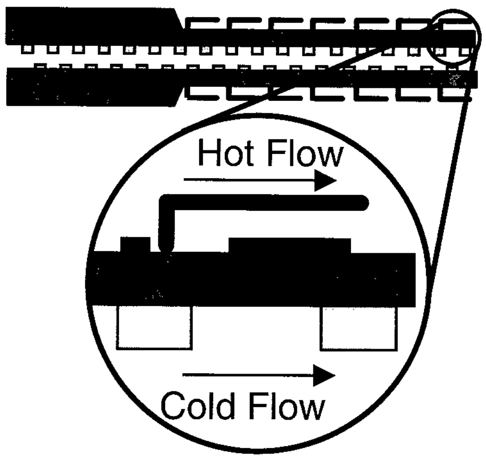


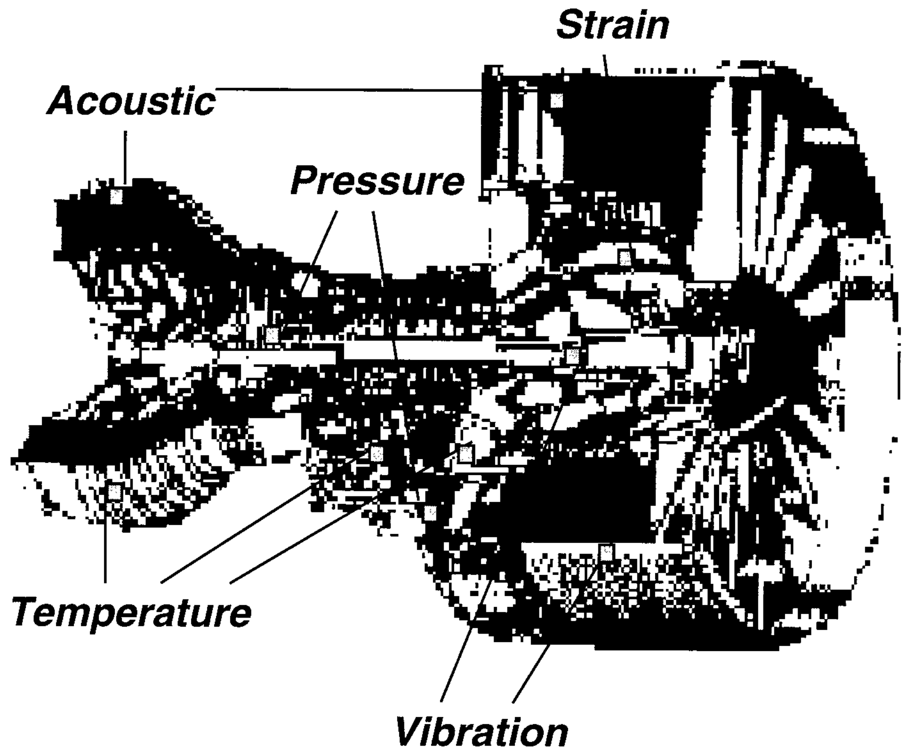
Fourth-Order Bandpass Filter with 71 MHz Center Frequency

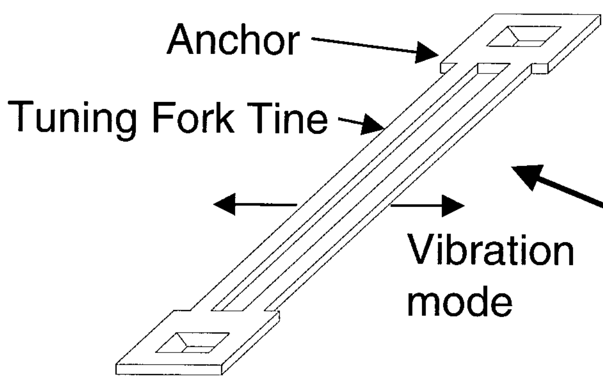
Univ. of Michigan
MEMS for Signal Processing

Robust Jet Engine

Micro heat fins 150 µm diameter, 500 µm tall, spaced on 1.0 mm centers on a 1.7 cm diameter rod. (LSU)



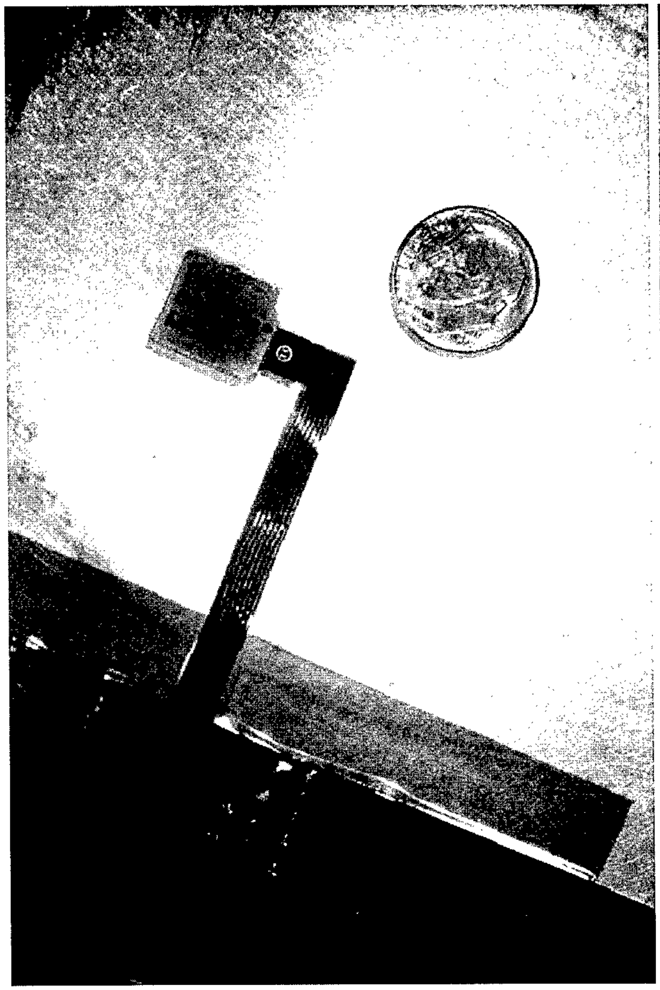


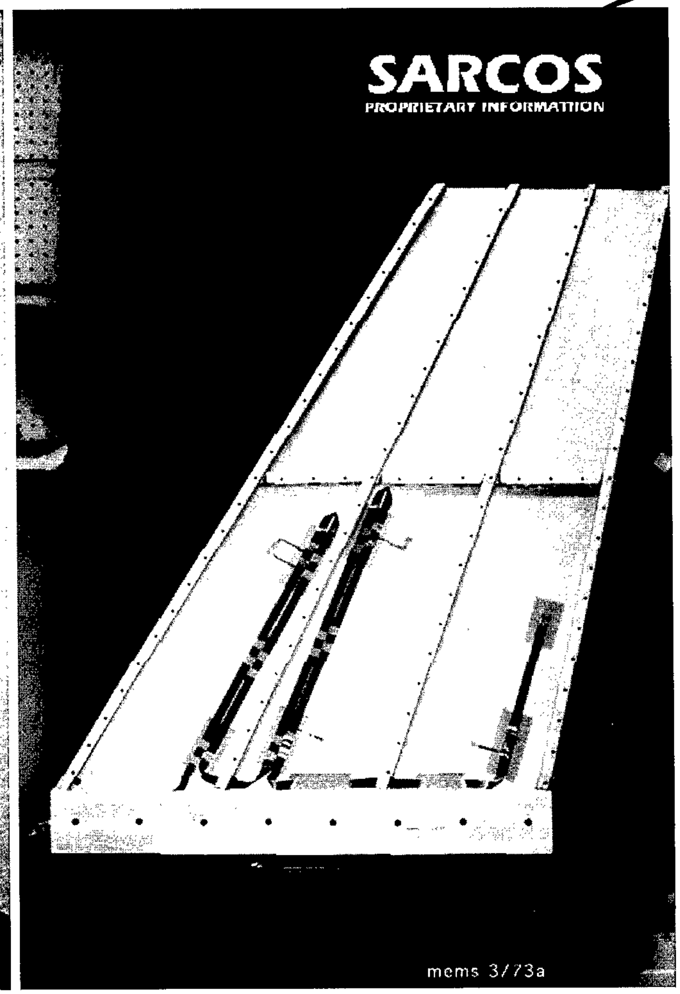


Micro resonant strain gage with over 10,000x sensitivity of metal foil strain gages. Nominal sensitivity 600Hz/µstrain. (UCB)

Approved for Public Release - Distribution Unlimited

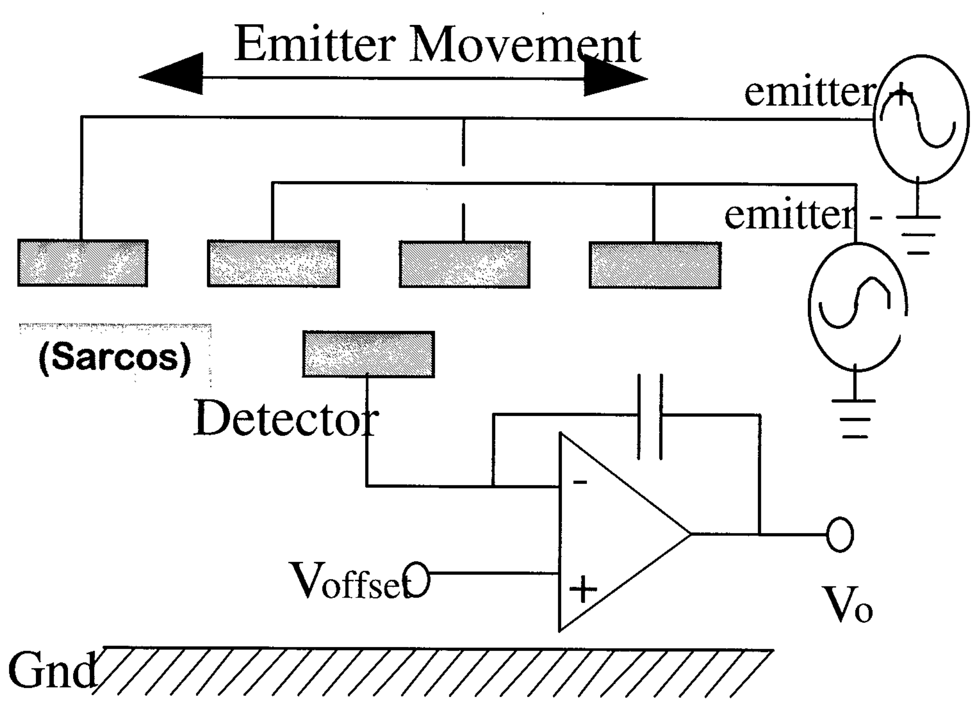
Robust Jet Engine



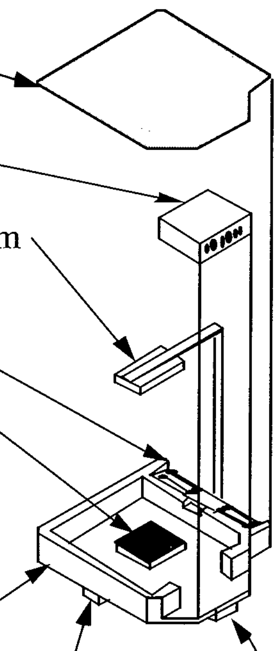


UAST Demo on 1/2-Scale F/A-18 Tail

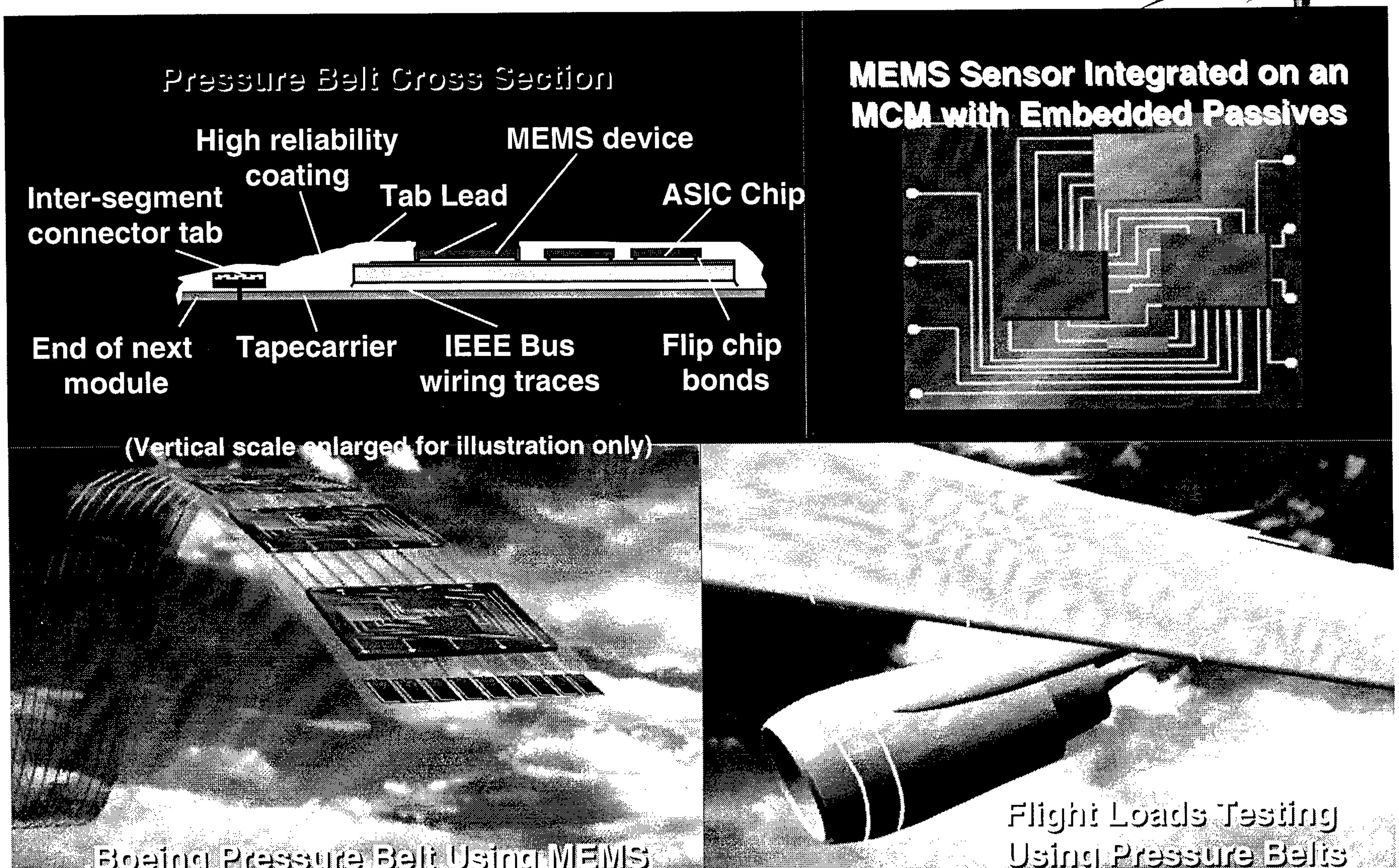
Robust Jet Engine



(Sarcos)

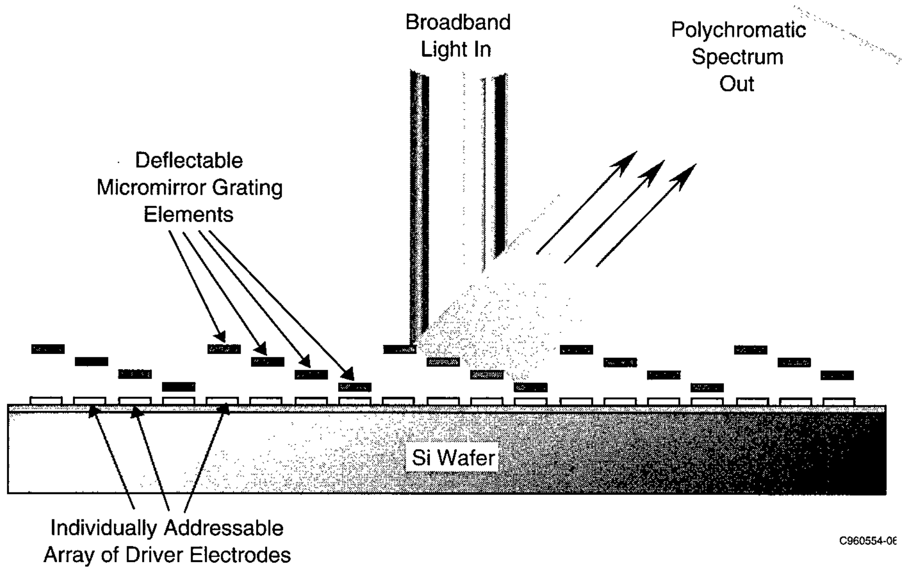


Robust Jet Engine

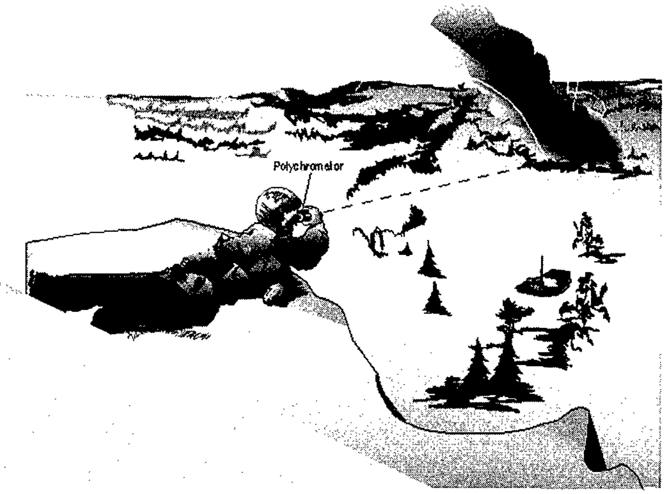


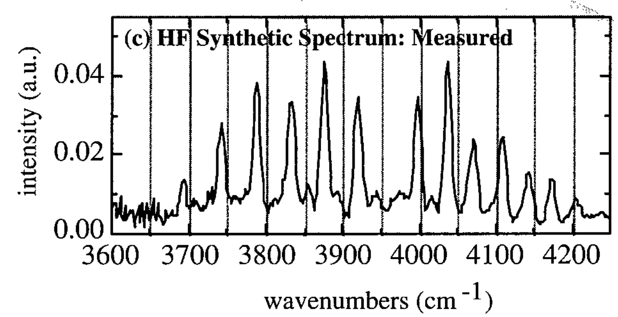
Micro Airborne Sensor/Communicator

MEMS Polychromator



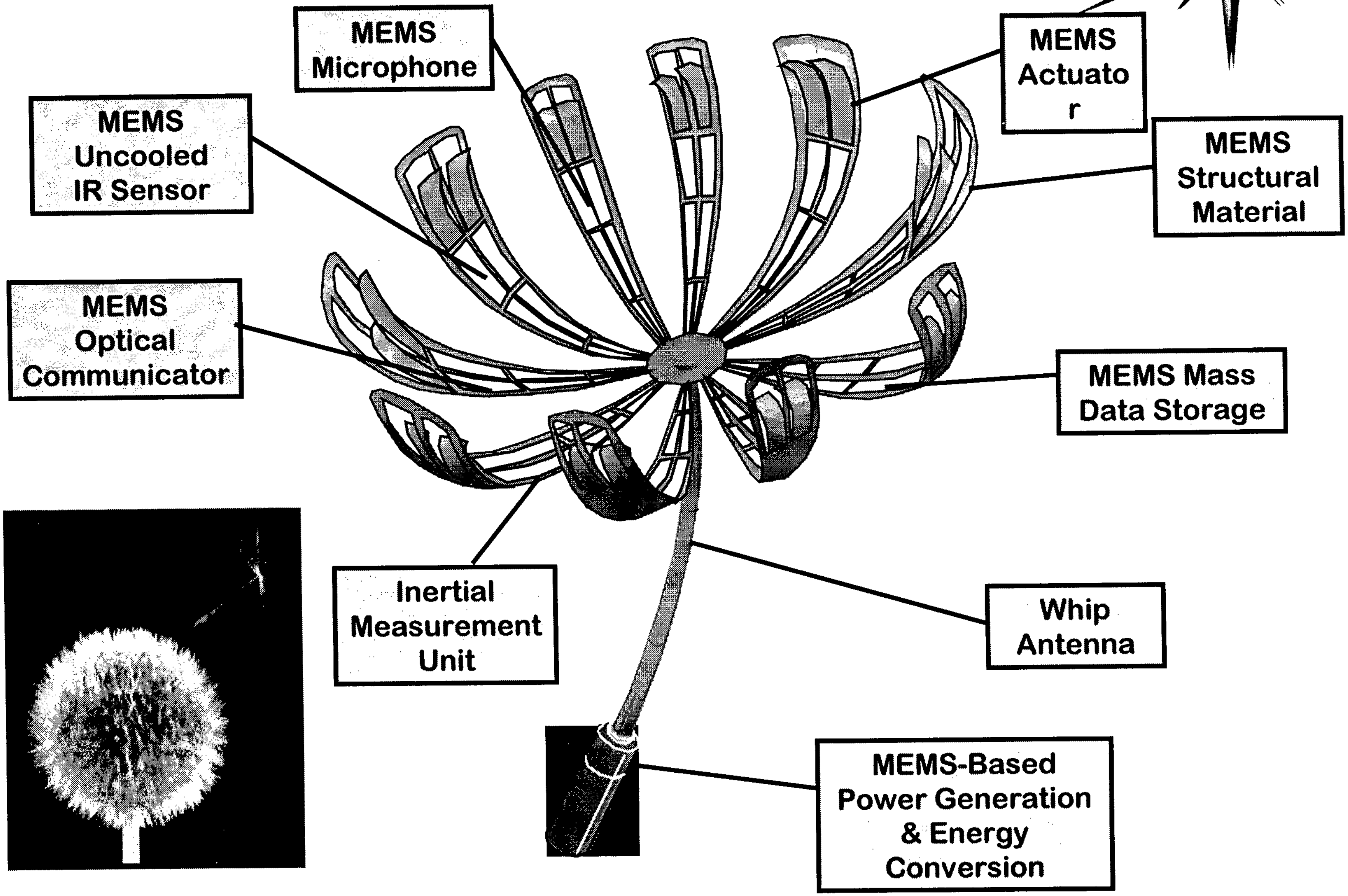
Honeywell Corp.





- A new concept for an electronically programmable, dark-field correlation spectrometer based on a MEMS diffraction grating.
- Leads to development of a miniature, electronically programmable remote chemical detection system for field use.

Micro Airborne Sensor/Communicator



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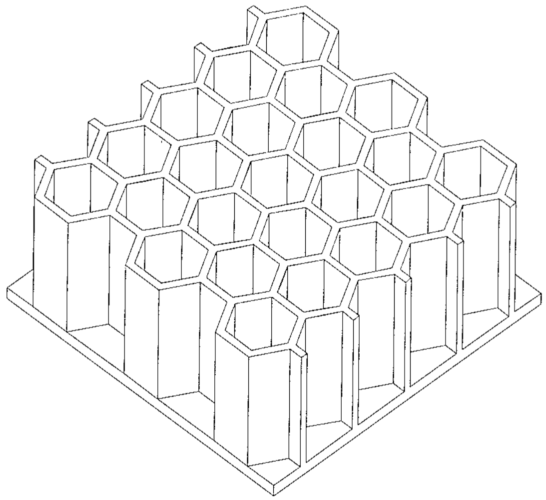
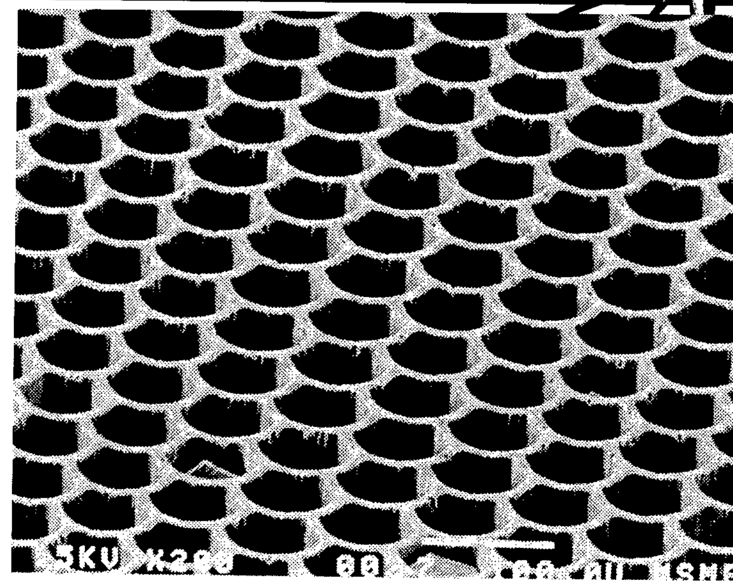
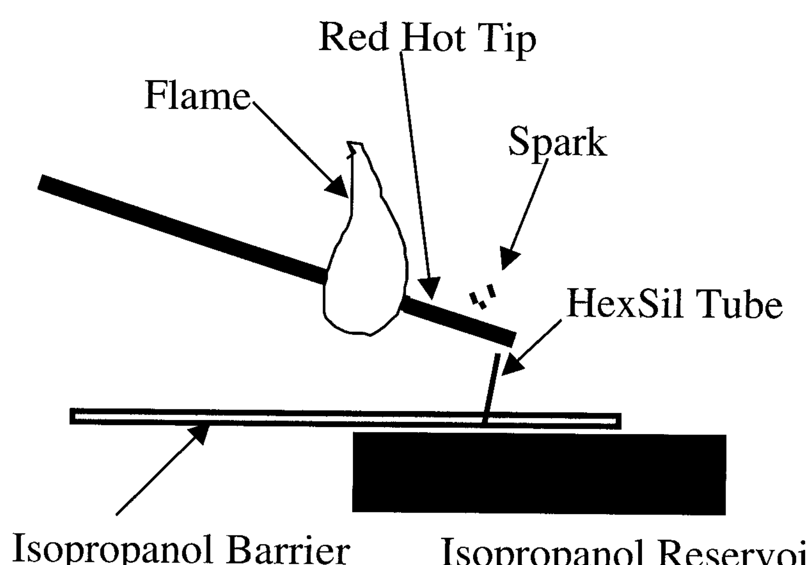
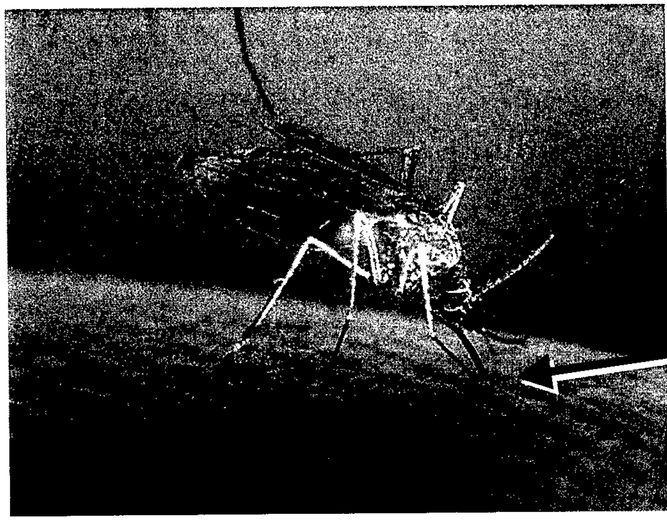
Micro Thermal-Chemical Power

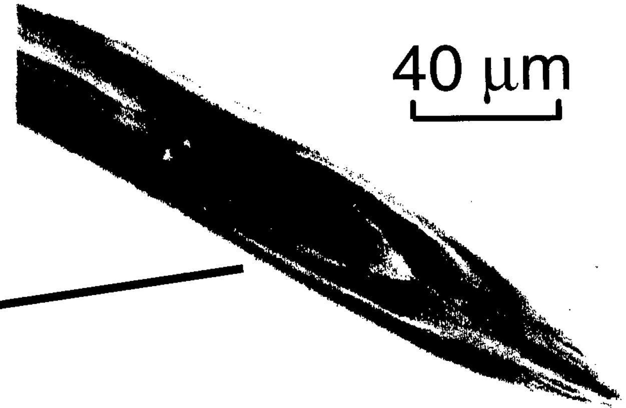


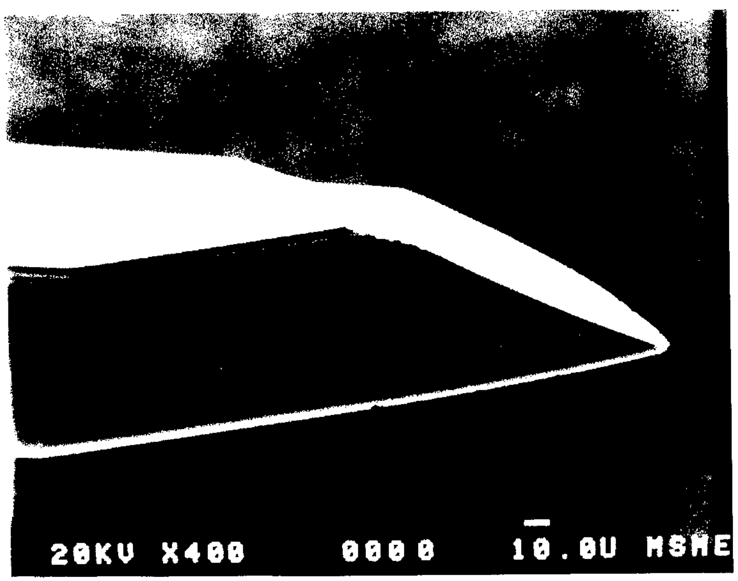




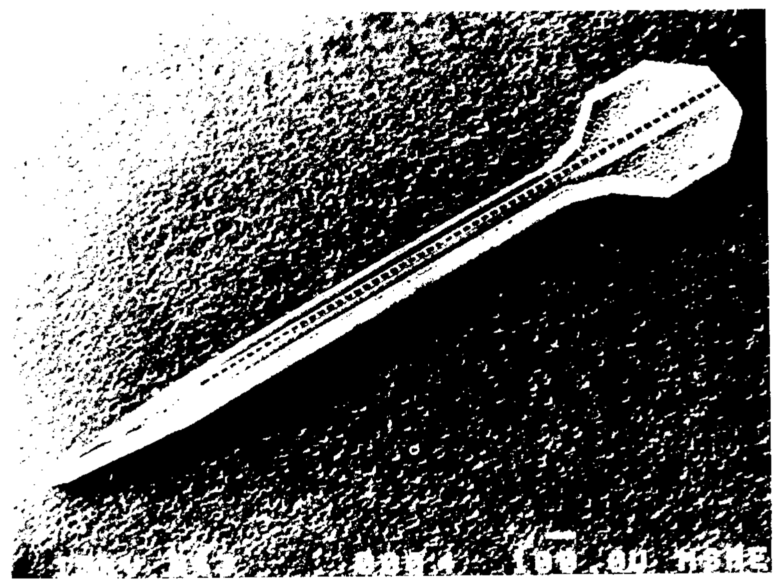
Micro Thermal-Chemical Power





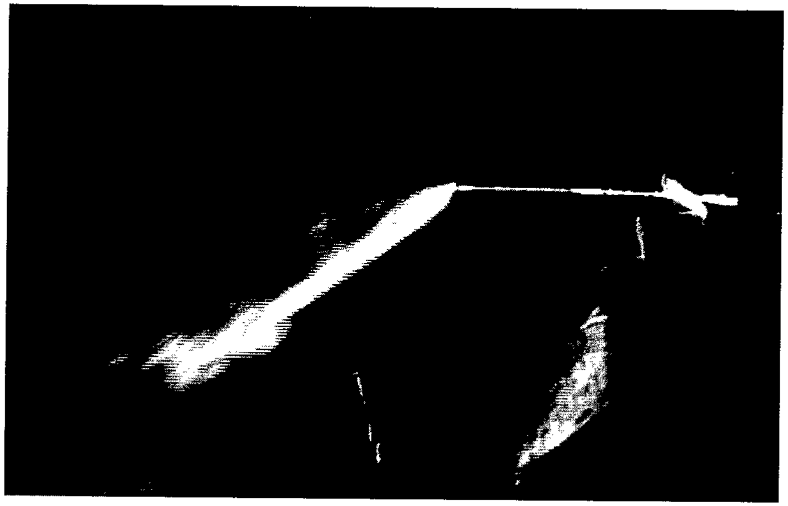


Lancet width = 170 μm

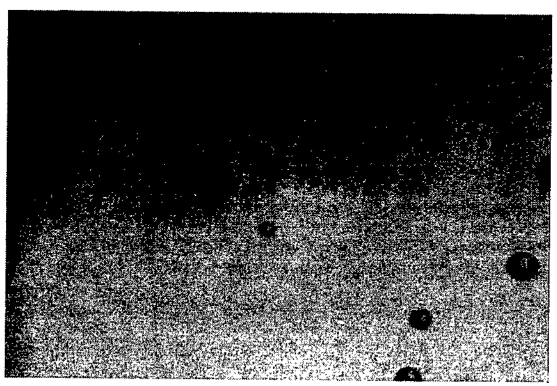


Needle width = 150 μm

Micro Thermal-Chemical Power

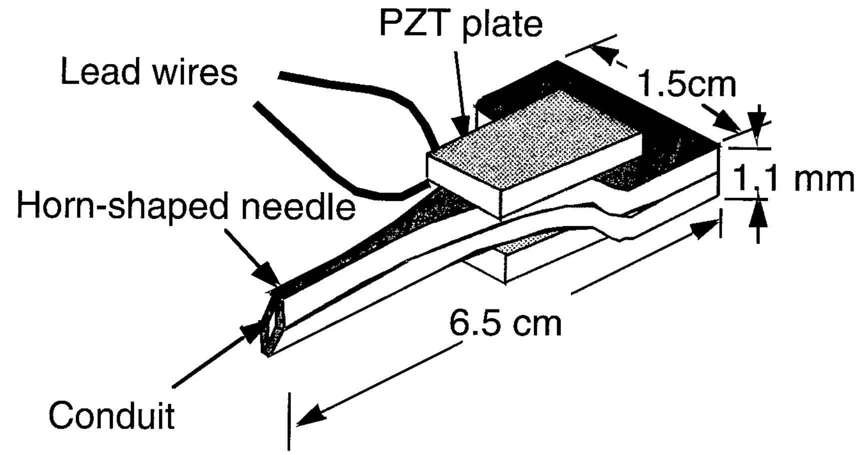


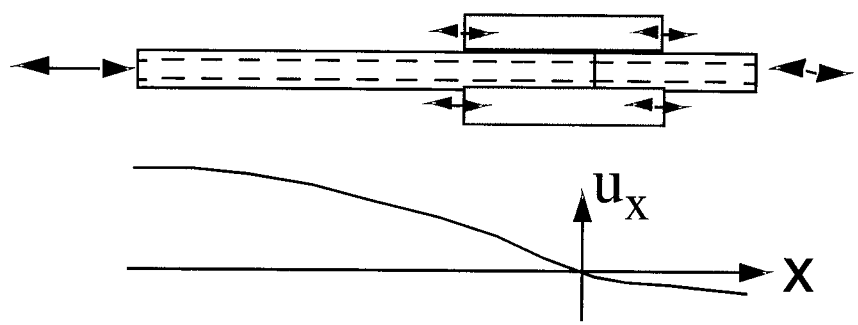
Water Droplets 20-35 μm at 72kHz



Ultrasonic Atomizer

(U of Wisconsin)





Axial Displacement Amplitude

Conclusions

MEMS is an enabling technology that will be part of both macro and micro systems.

- Extreme miniaturization of low-power communication devices.
- Networks of sensors and actuators on macro devices for robustness and performance.
- Integrated systems for airborne sensing/communication.
- Thermal-chemical power on the microscale, for the microscale.

Advanced Microelectronics

Dr. Daniel J. Radack

DARPA

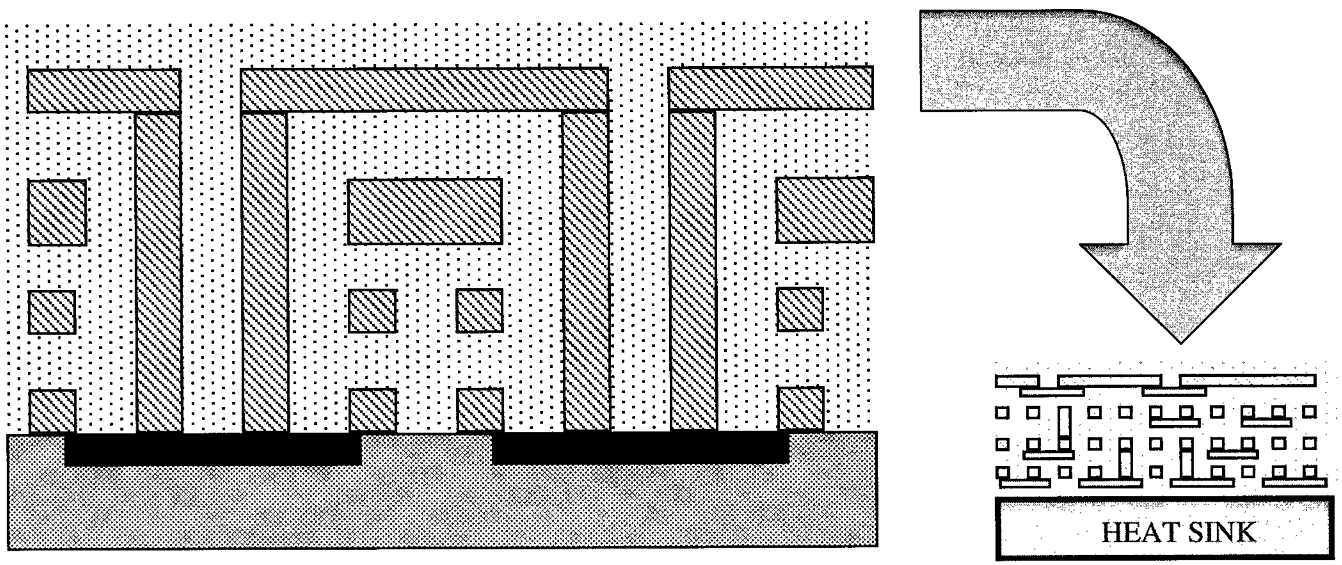
MTO

Flow of Talk

- Overview
- 25nm Transistors
- Vertical Devices
- 3D Integration
- Circuits and Structures

Terascale Integration

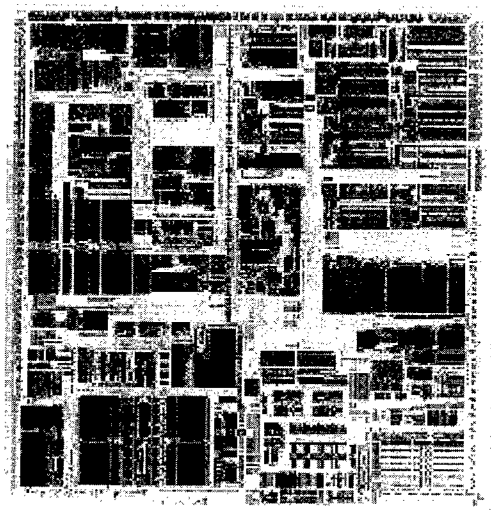
2D Transistors

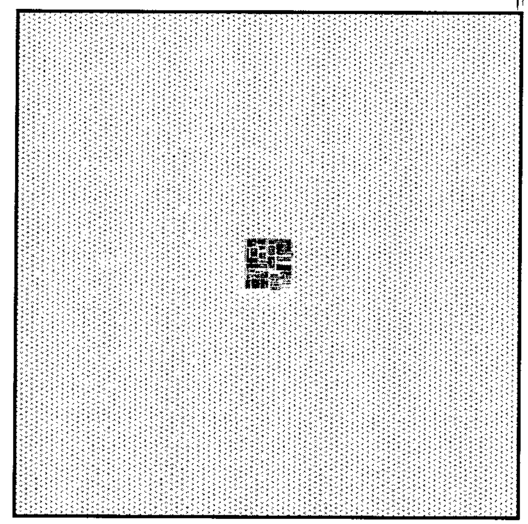


3D Si Circuits

DARPA MTO

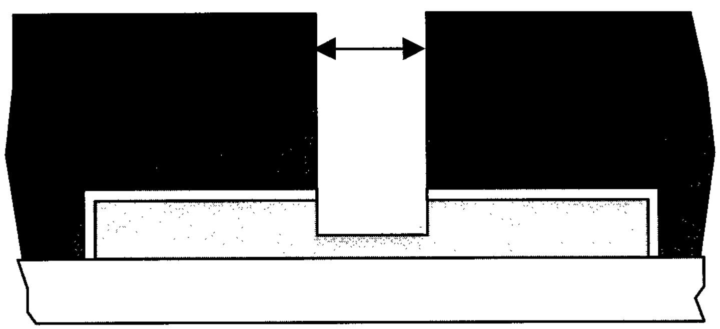
Design Opportunity



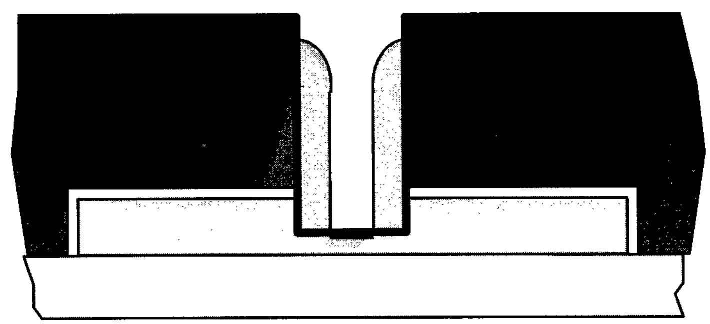


100's of billions of 25nm transistors available for design of monolithic electronic systems

Silicon Slot FETs



1. Etch slot



2. Spacer and Gate Ox

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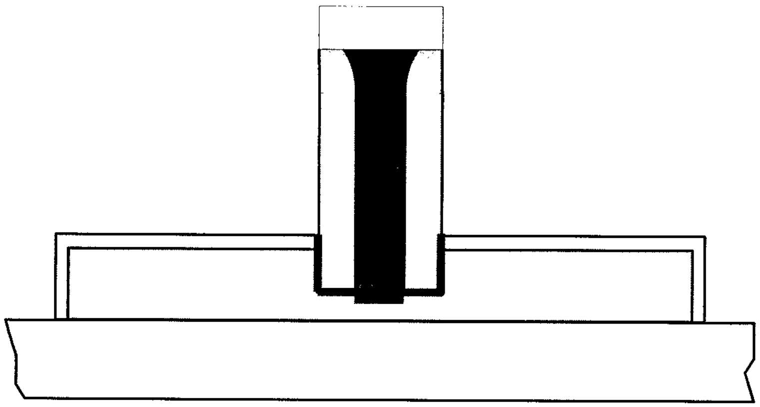
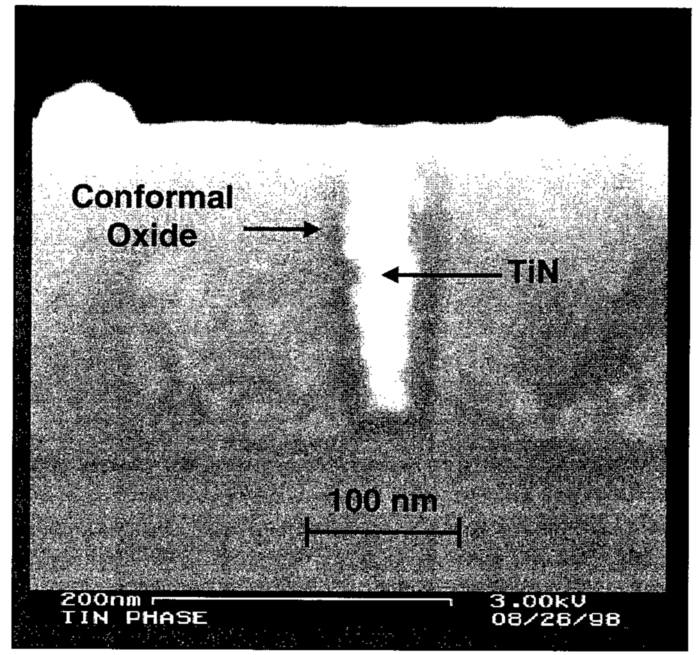
Silicon Slot FETs

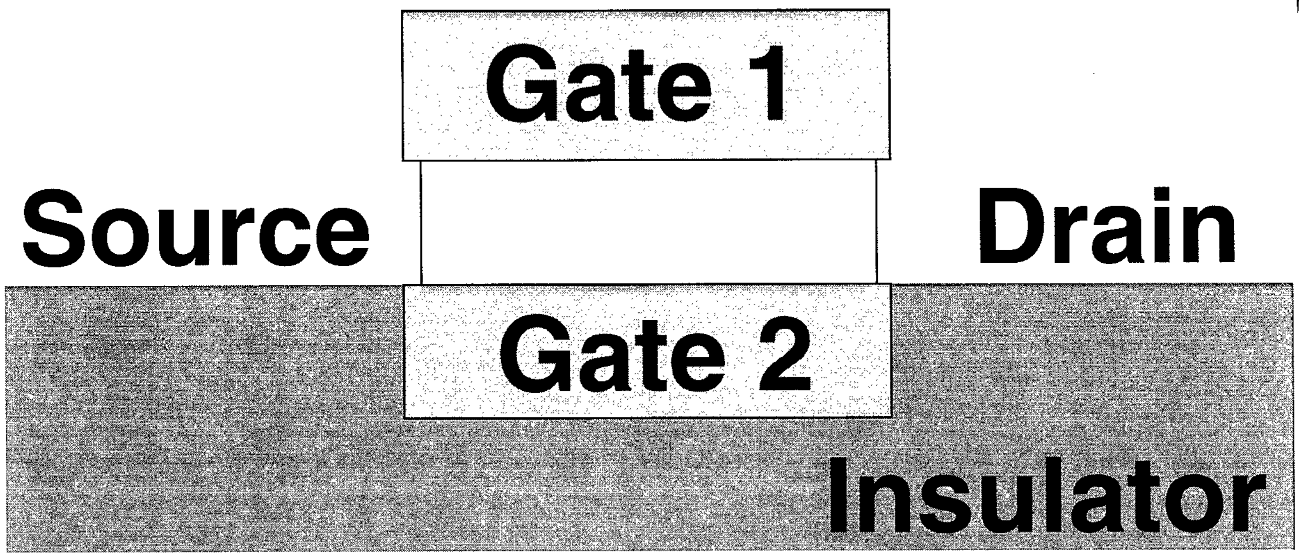




3. Gate electrode and junctions

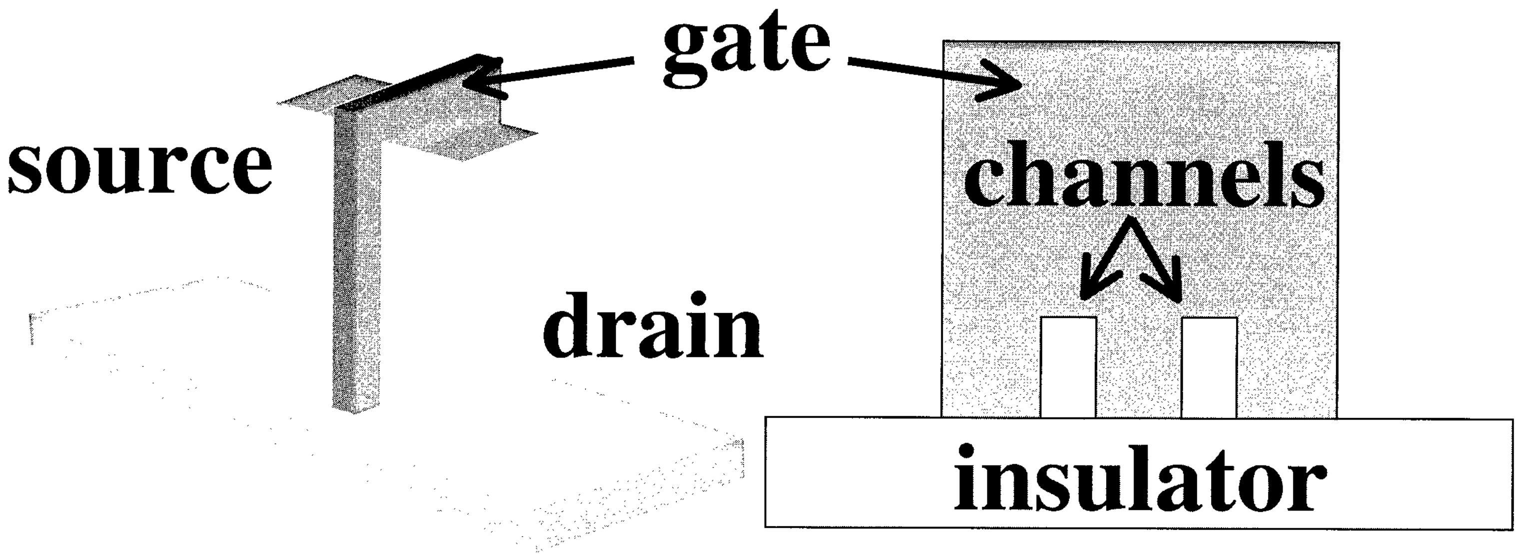
Slot FET's functional

Planar Double Gate



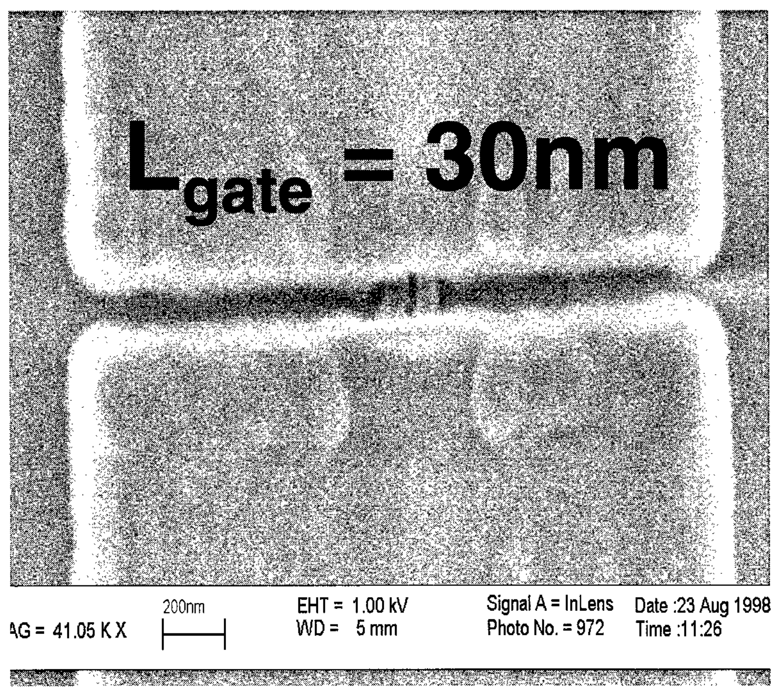
Simple device concept, difficult to self-align gates

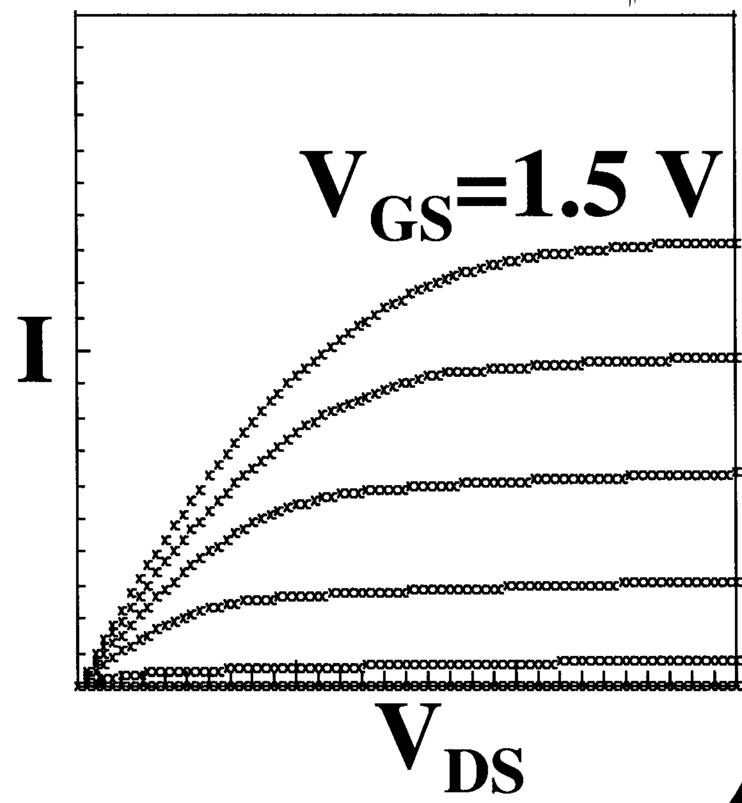
Folded Channel FET



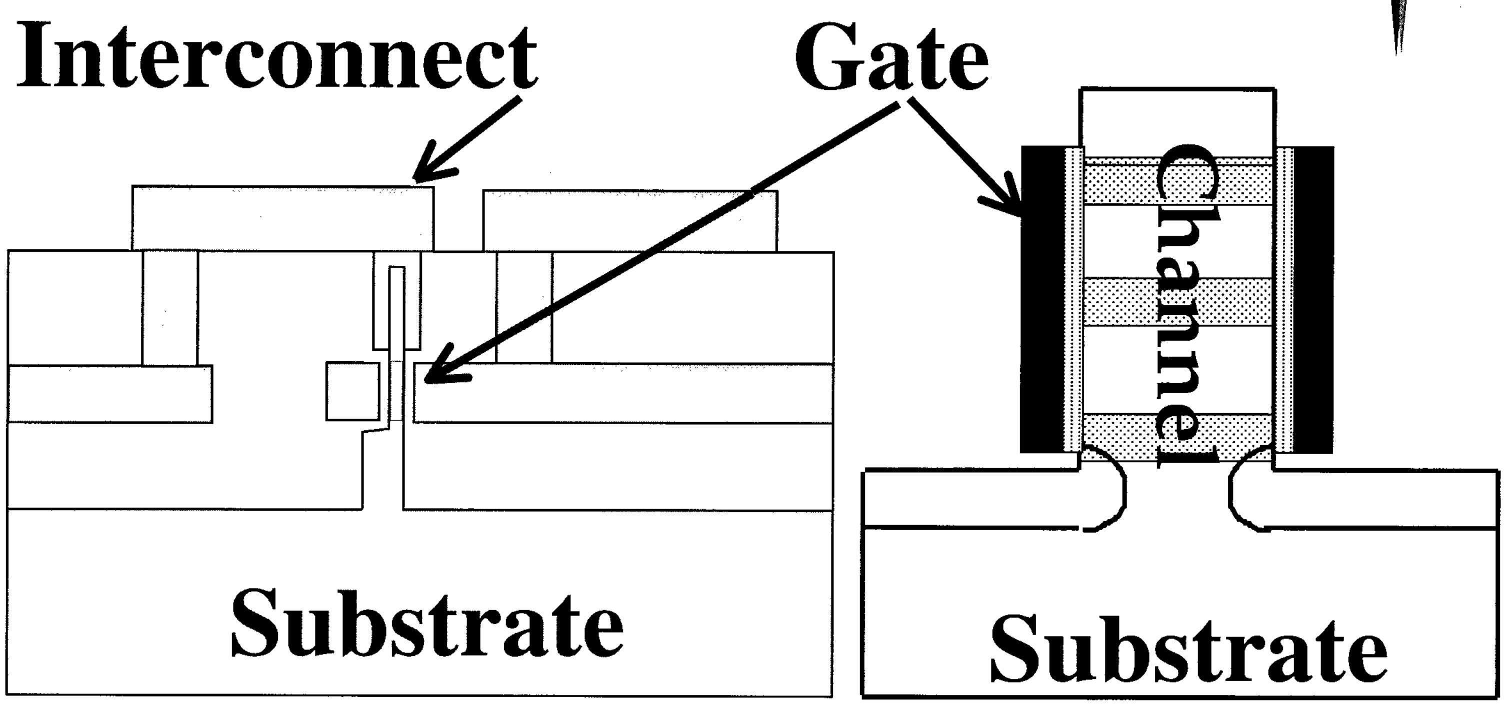
Manufacturable double gate transistor

Double Gate FET



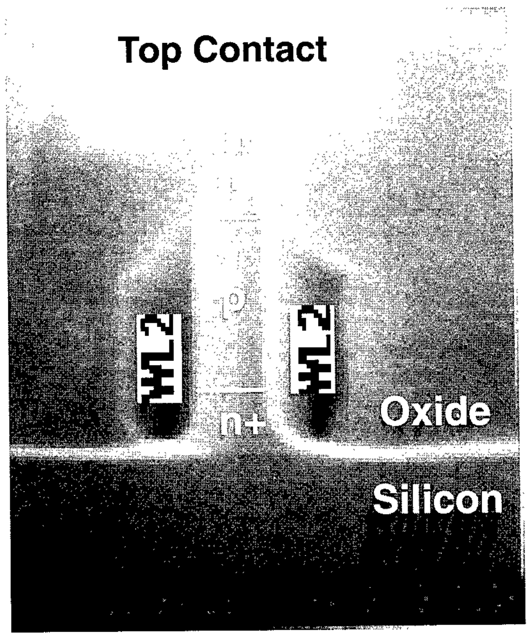


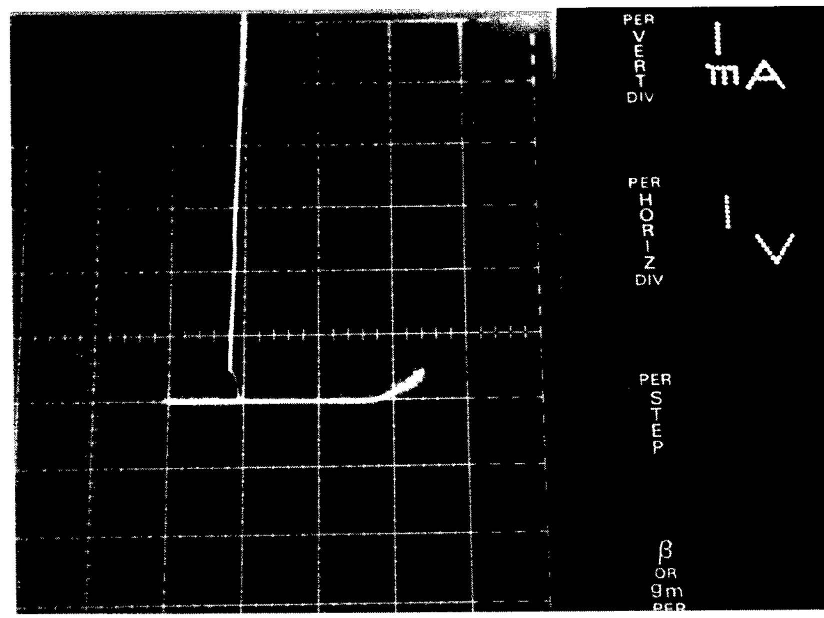
Vertical Devices



Channel engineering and greater functionality per area

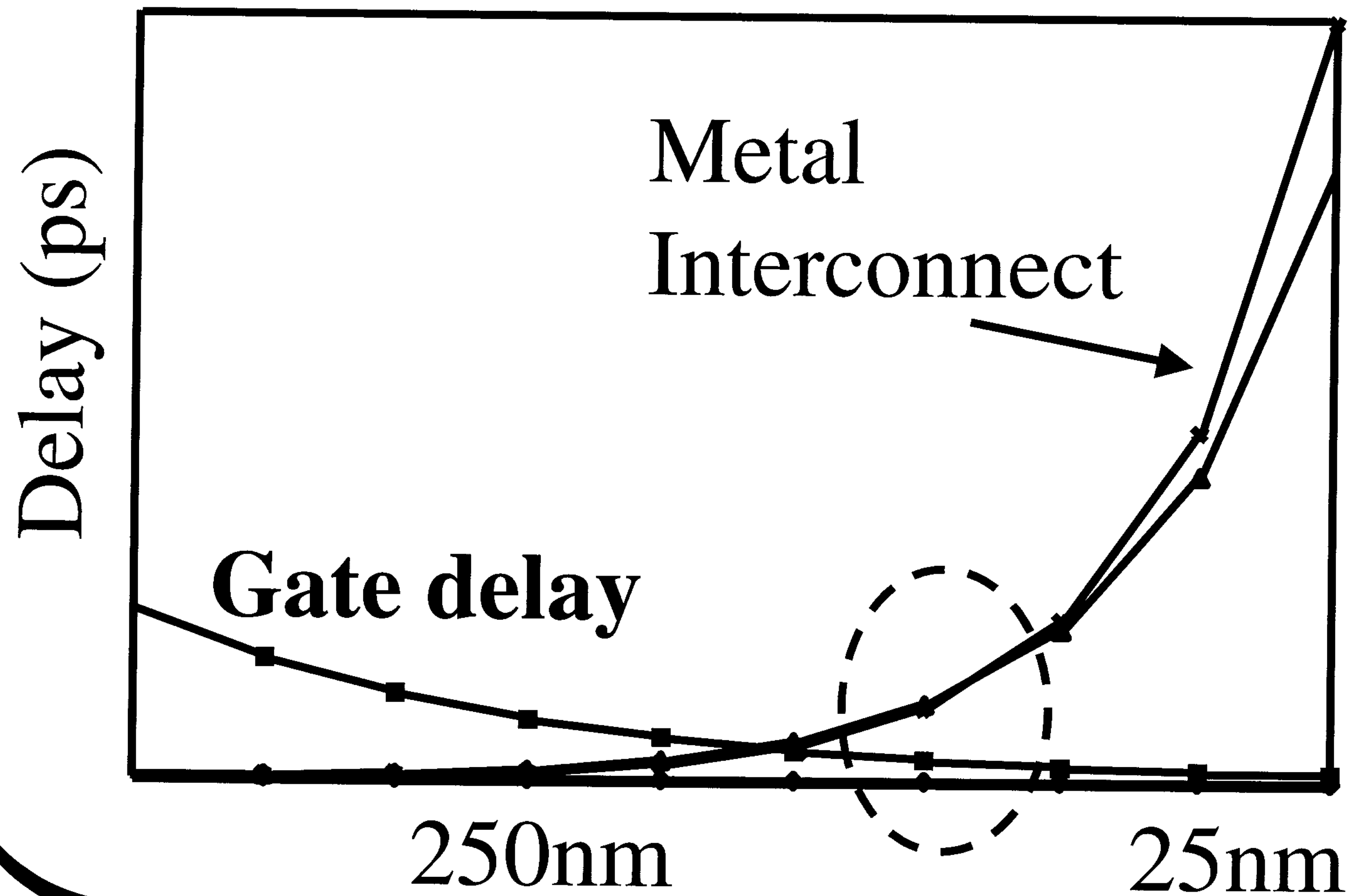
Vertical SRAM



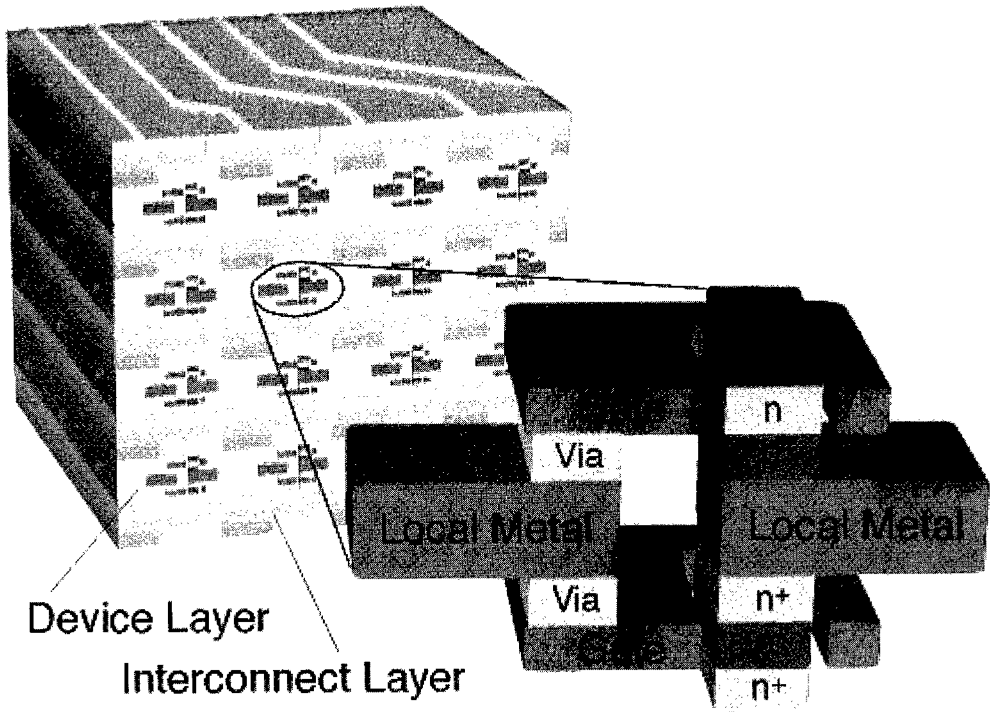


Compact, low leakage, latching

Interconnect Challenge



3D Integration



Integrated circuit on multiple layers

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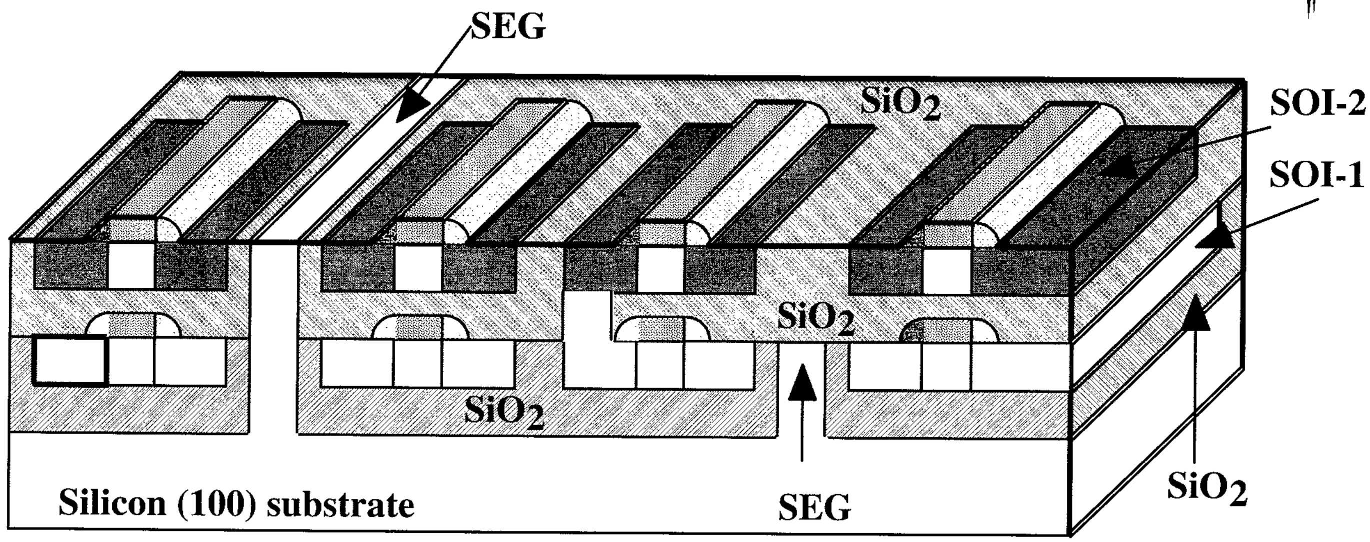
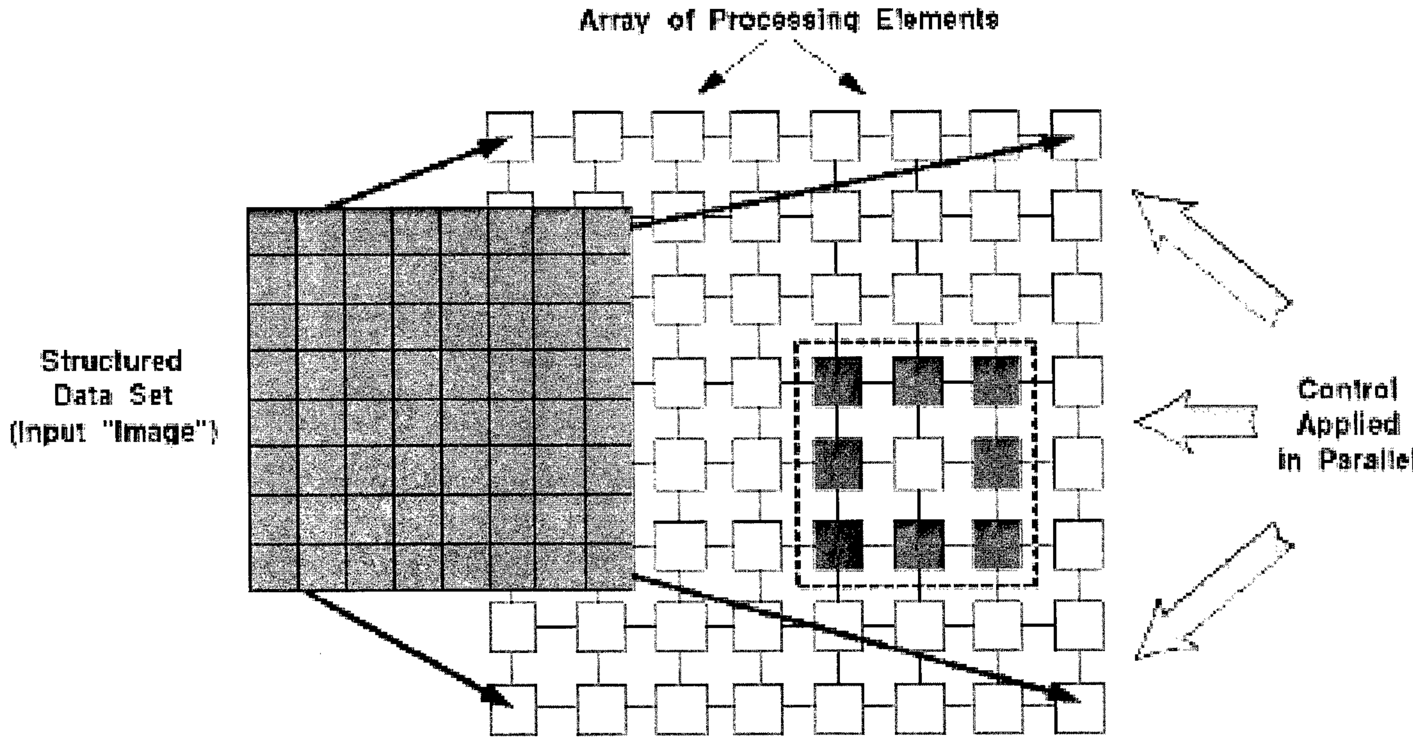
Multiple Si Layers



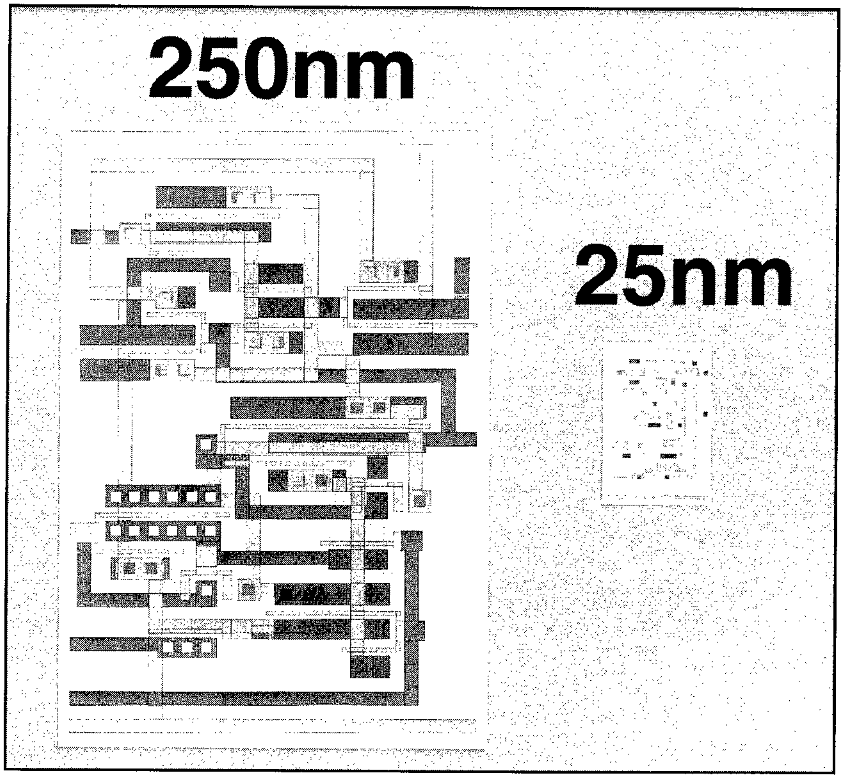
ELO/CMP demonstrated for 2 layers with low leakage transistors

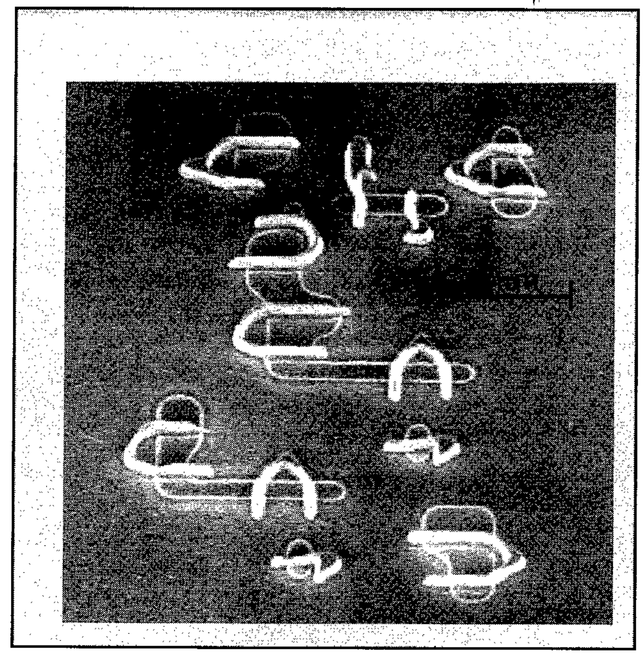
Pixel Processor



Local comm., constrained area

25-nm Circuit Demo





Design rules for 25nm process

Summary

- 25nm transistors work!
- Vertical devices have functionality/area advantages
- Moving toward integration and circuit experiments

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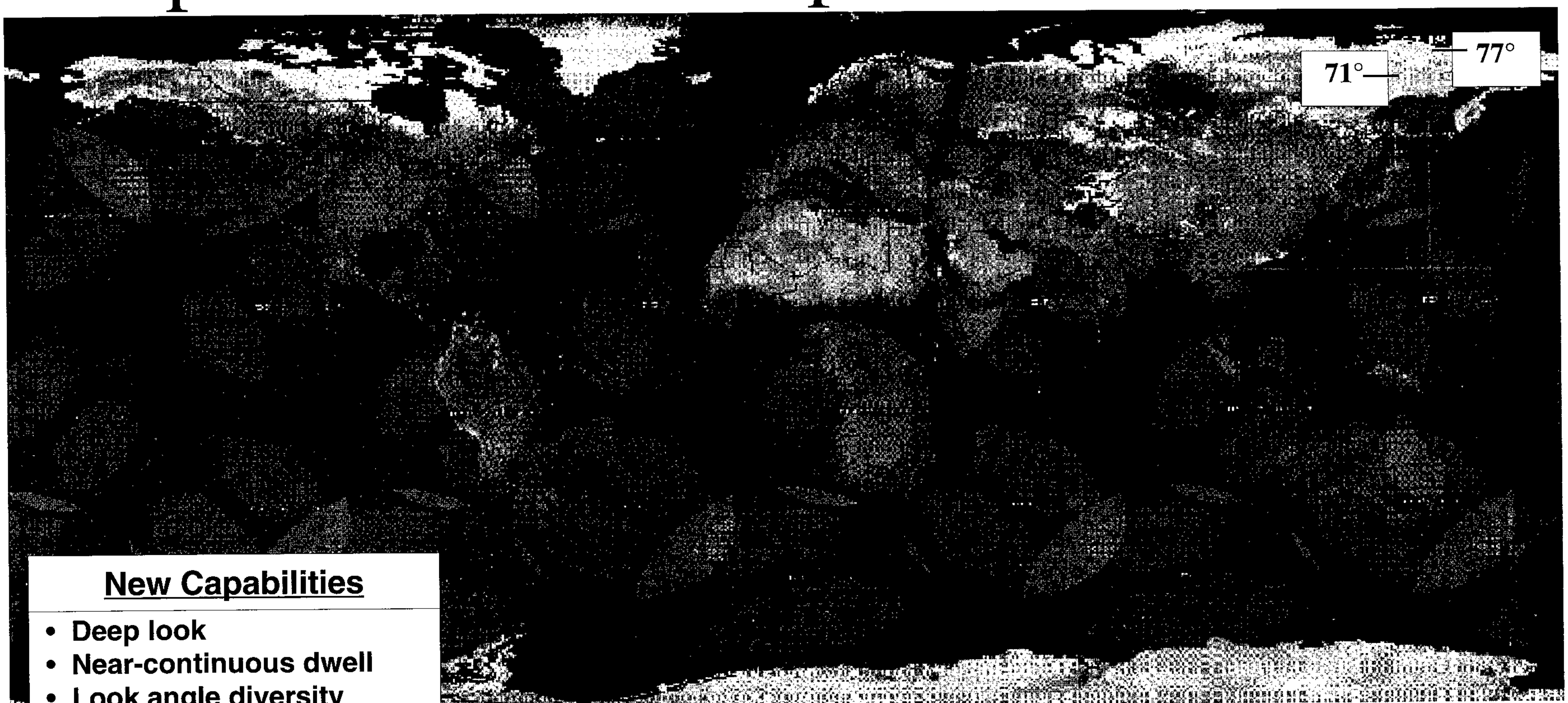
DISCOVERER II

USAF • DARPA • NRO

Program Vision

- Capable Affordable space-based radar

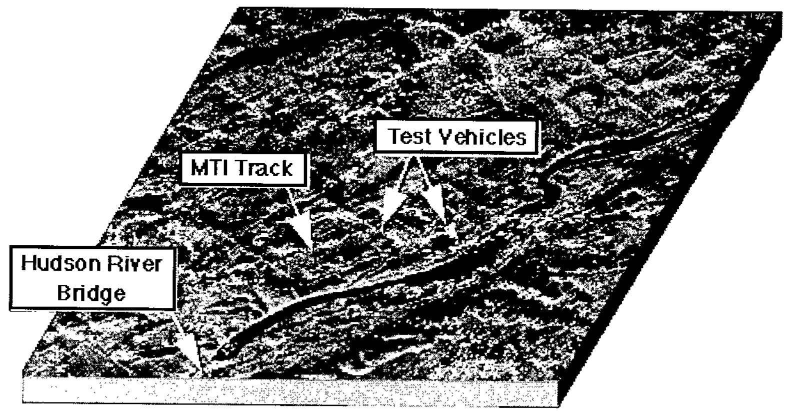


New Capabilities

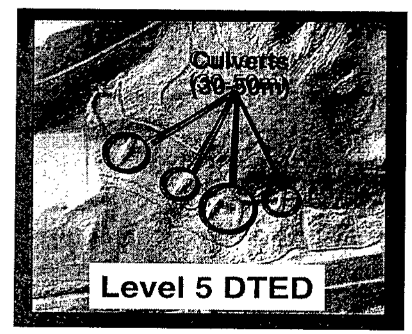
- Deep look
- Near-continuous dwell
- Look angle diversity
- 3-D change detection

Objectives

- GMTI Collection
- SAR Imaging
- Affordability
- Dynamic Tasking
- JTF/Theater Downlink Commander
- Collection of Precision Digital Terrain Elevation Data (DTED)



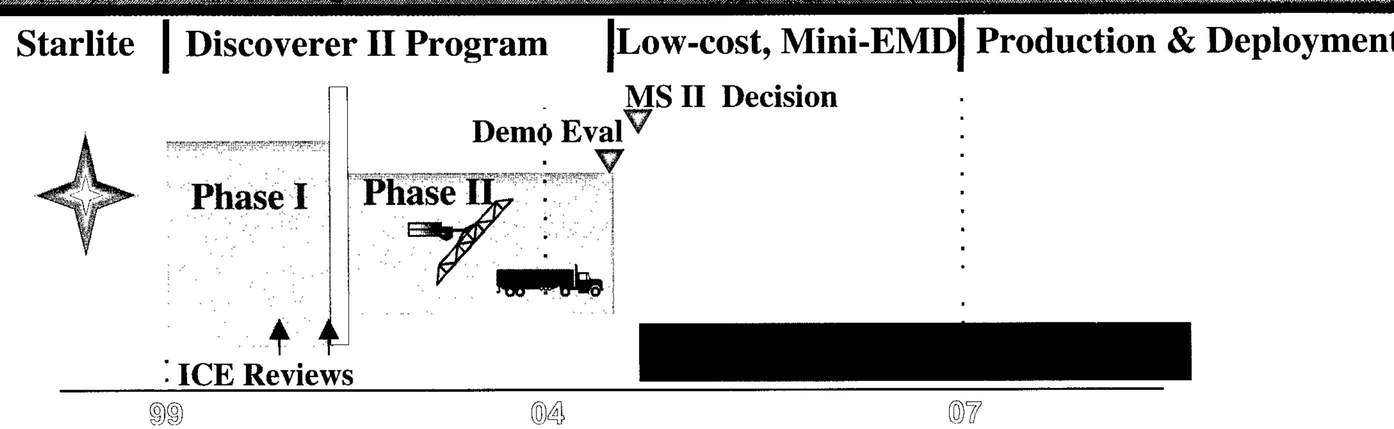
MTI Overlaid on SAR Image



Definition

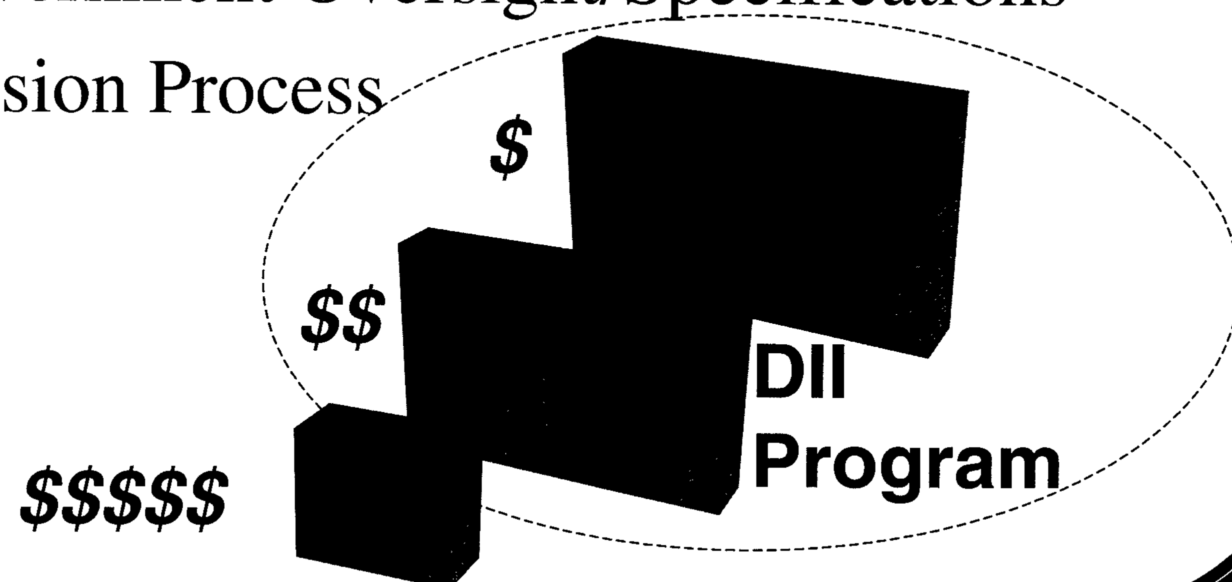
- Technology development and demonstration (Design to Cost) program
- "Objective System"
- Two satellites/Modify ground systems
- Transition to reduced risk EMD

Discoverer II: An advanced technology demonstration on the path to an affordable production system [Goal: 1) $100M/bird 2)< $10.0B life cycle cost]



Key Themes

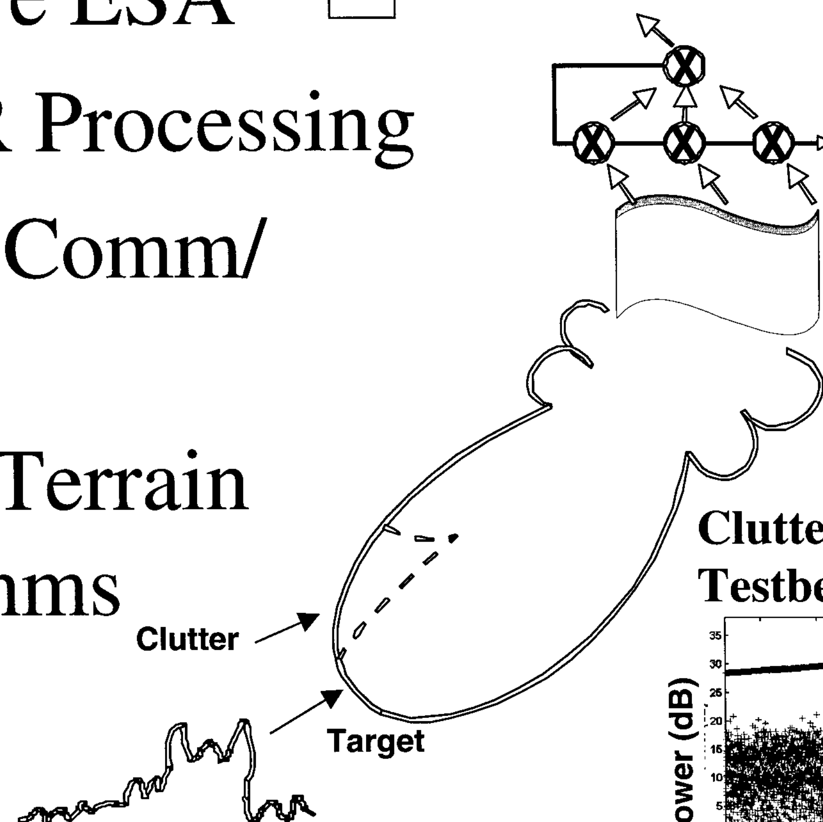
- Cohesive, Focused Program with Balanced Risk Reduction and Core Elements
- Maximum Industry Innovativeness/Involvement
- Limited Government Oversight/Specifications
- Staged Decision Process

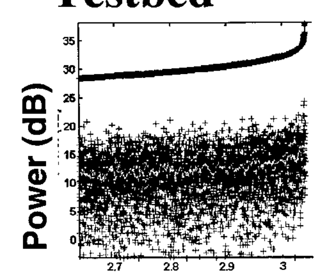


Technical Challenges

?

- Spaceborne Active ESA
- HRR-GMTI/SAR Processing
- Ground Segment Comm/ Processing
- High-Resolution Terrain Mapping Algorithms

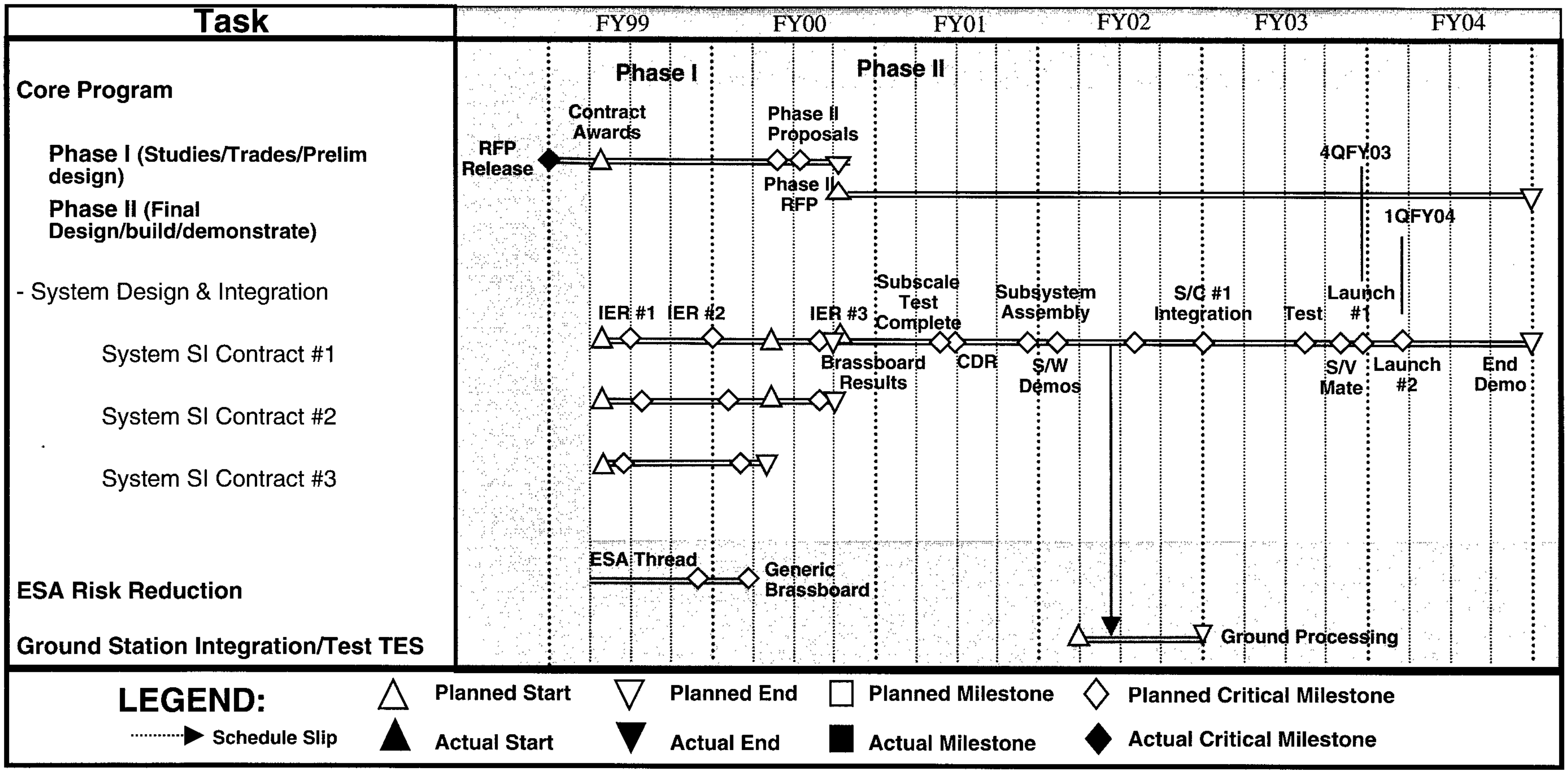




Key Contractors

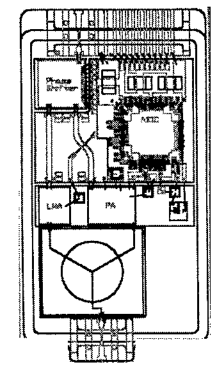
- System Integration Contractors
  - Lockheed Martin Astronautics
  - Spectrum Astro
  - TRW
- Risk Reduction Performers
  - Northrop Grumman
  - Raytheon
  - MIT/LL
  - Alphatech
  - Johns Hopkins/APL
  - AFRL
  - ERIM International
  - Aerospace Corp

Program Schedule

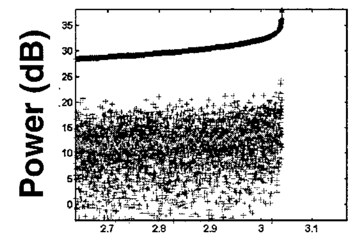


Significant Accomplishments

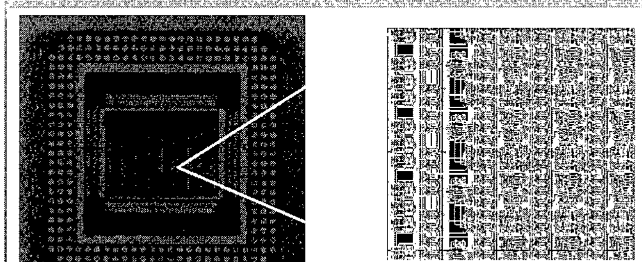
- Space Qualified Multiple Advanced T/R Module Designs
- Signal Processing Designed
  - STAP
  - Airborne Collects
- VLSI Processor Developed
  - .25 micron
  - 24 Gops/watt



Clutter Removal Testbed



Wideband Receiver



FIR Chip
24 Gflop/watt

6M Transistors
0.25 micron

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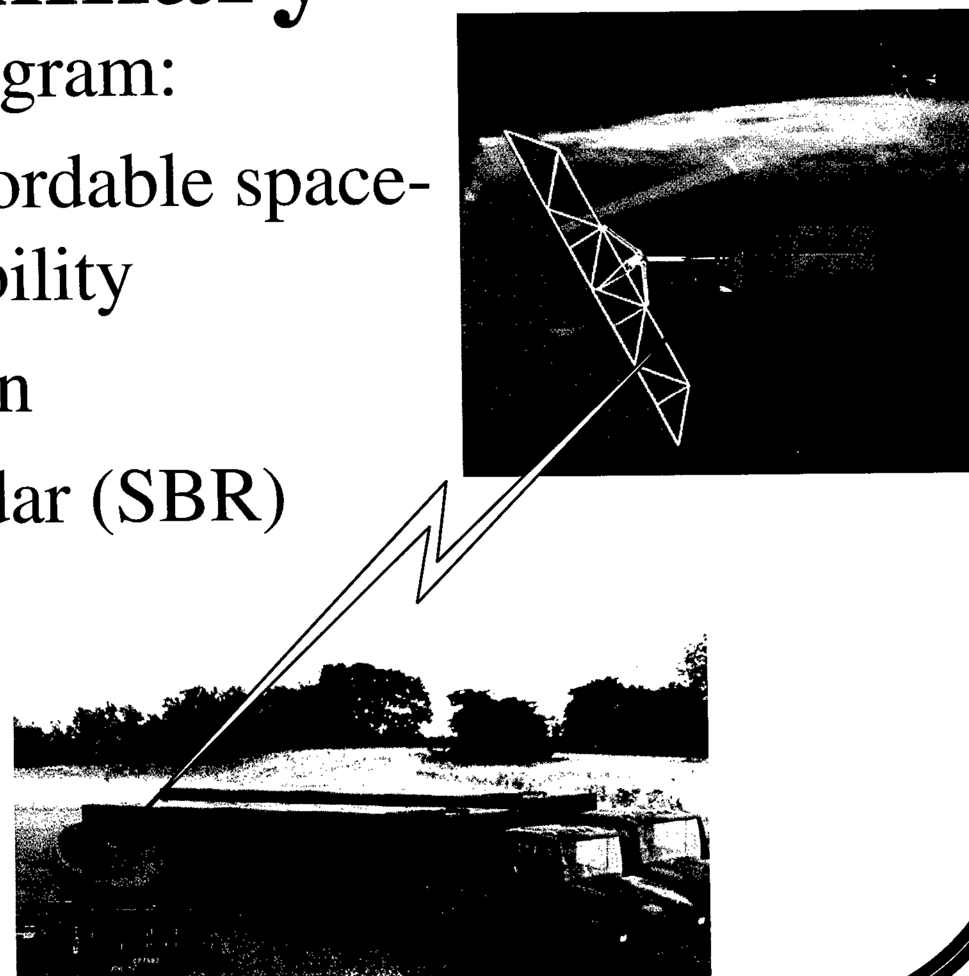
Demonstration Summary

- Joint Demonstration Program:
- Technical feasibility affordable space-based GMTI/SAR capability
- Objective System Design
- Fly (2) Space-based Radar (SBR) R&D satellites
- Tactical ground stations



Micro Adaptive Flow Control

Tactical Technology Office

DARPA Tech 99

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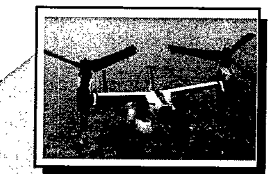
MAFC

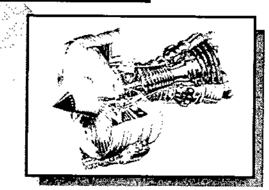
MICRO
ADAPTIVE
FLOW
CONTROL

Controlling large scale flow behavior using small scale/low energy actuation

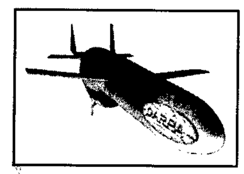
ENABLES A SPECTRUM OF MILITARY APPLICATIONS



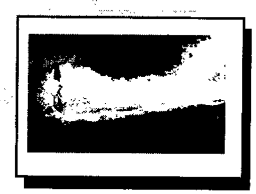
Aircraft



Engines



Munitions



Maritime

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Enabling Generic Actuator Concepts

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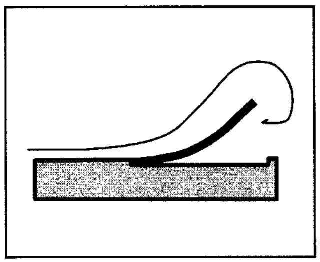
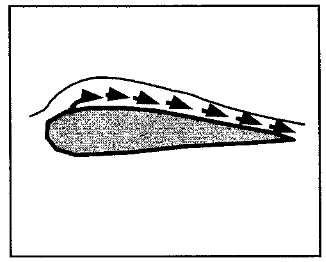
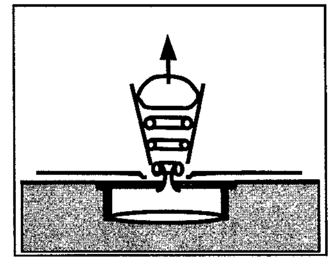


MEMS/Smart Materials



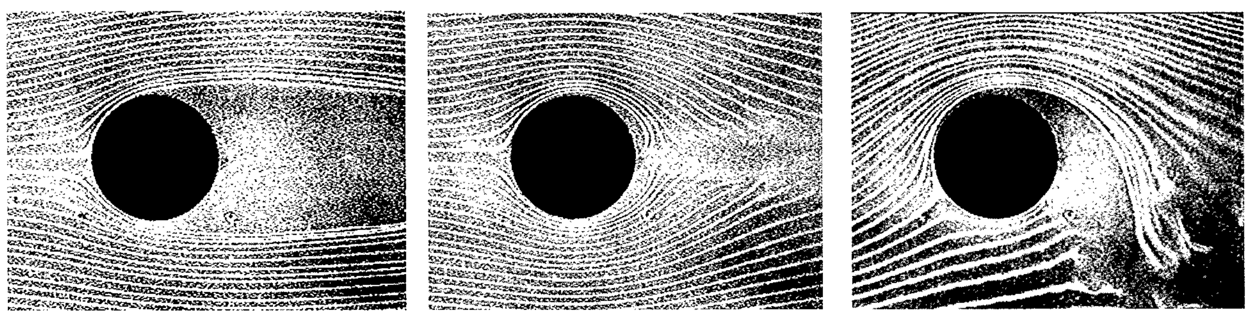
Pulsed Blowing



SyntheticJet

Flow Around a Cylinder

Synthetic Jet Closes Wake, Eliminates Form Drag, Controls Circulation



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Program Goals

- Demonstrate large scale flow control with small actuators
- Demonstrate robust control under real flow conditions
- Achieve radical performance enhancements with MAFC

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Program Strategy

- Identify System Level Application
- Develop MAFC Concept
- Design and develop actuators and controllers
- Validate MAFC performance
- Integrate and demonstrate system

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Current Status

- Phase II Tech. Development & Feasibility Demonstrations
  - Radical propulsion system performance
  - Aerodynamic tailoring for flight controls and performance
  - Precision munitions trajectory control

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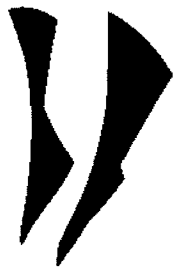
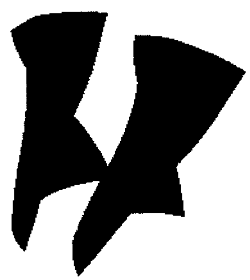
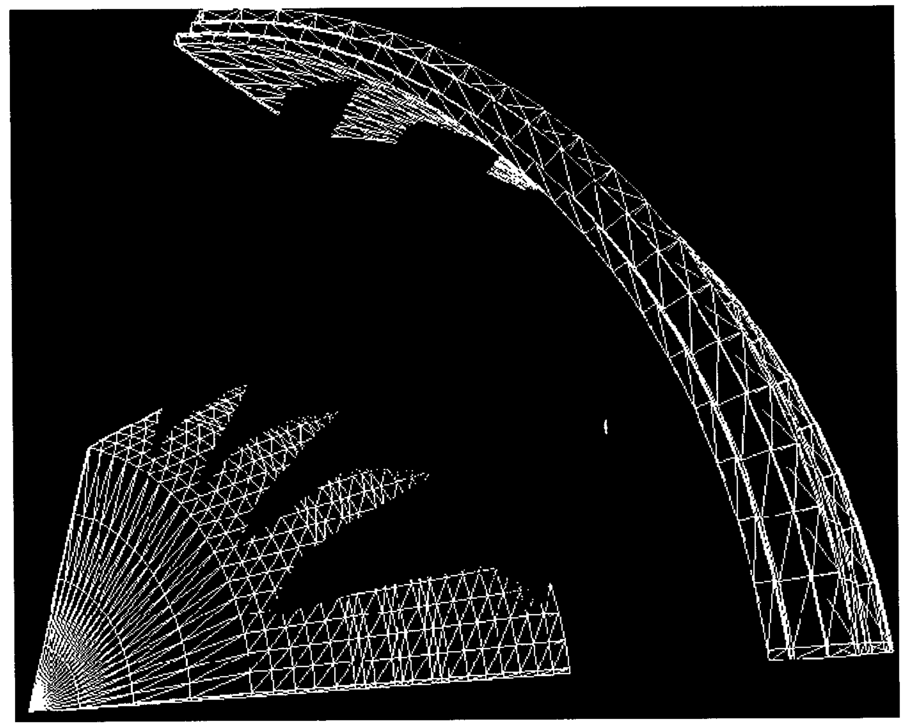
Aspirated Compressor



Conventional Rotor Blading
3 Stages



Aspirated Rotor Blading
1 Stage



Aspirated Rotor with Tip Shroud
Pressure Ratio = 3.8

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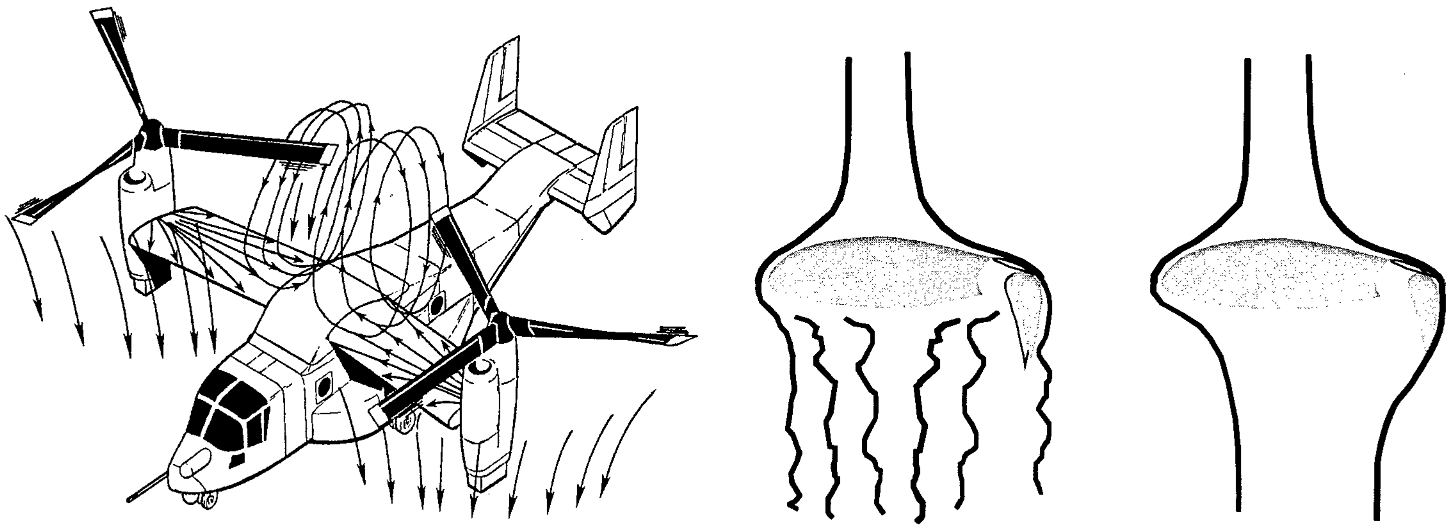
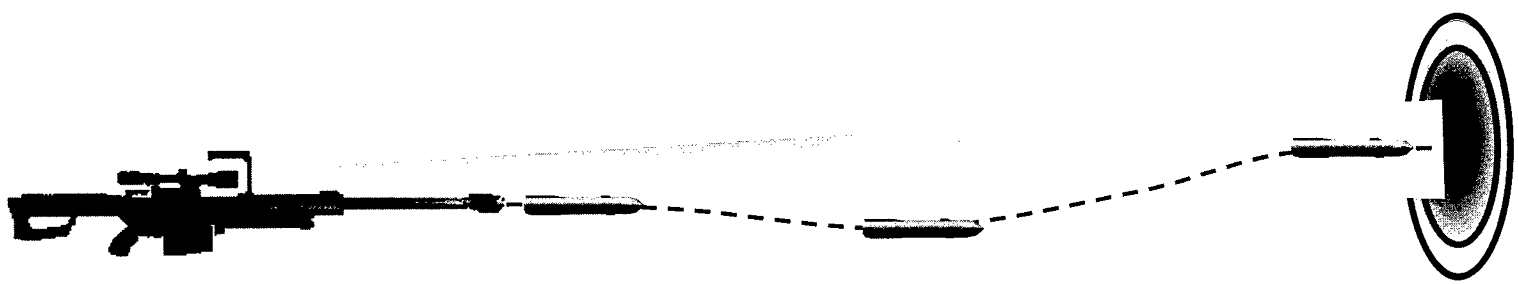
V-22 Lift Enhancement



Close wake with flow control on flaps to reduce downwash and increase V-22 lifting capacity **30%**

Munitions

- Lutronix - Range Extended Adaptive Munition



Fins steer 50 cal munition to reduce wind drift and ballistic drop for increased accuracy at longer ranges

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Future

- Planning BAA for Fall 1999
- Develop and demonstrate technical feasibility of MAFC concept
  - System level realizability
  - System level demonstration of radical performance
- Munitions, Maritime, Aerodynamics, Engines
- DARPA is interested in hearing from the community as to potential applications and approaches.

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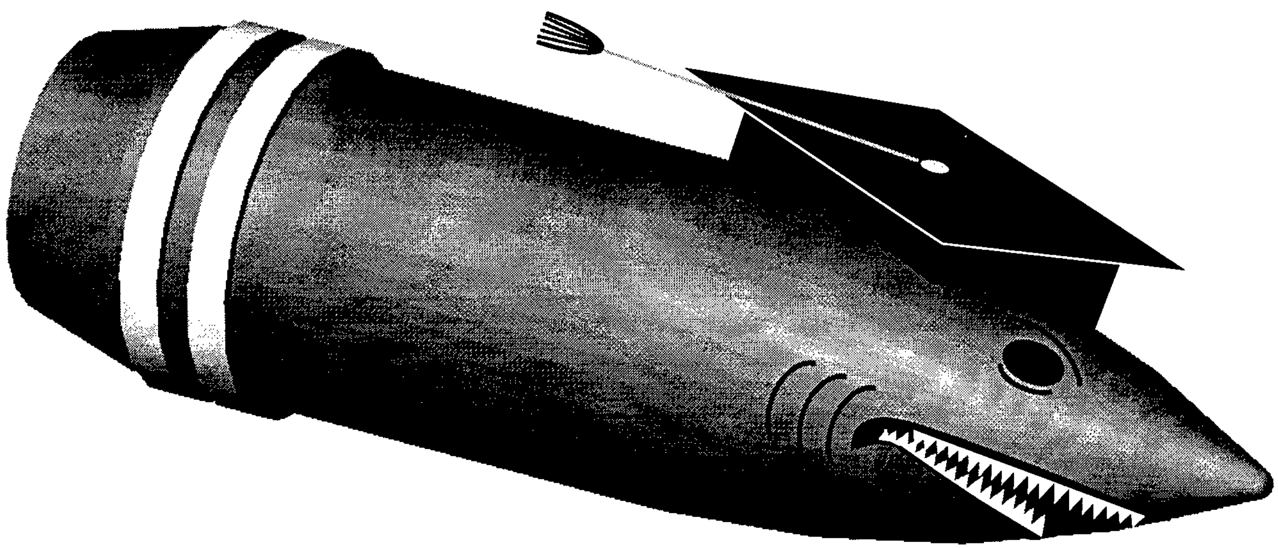
Smart Bullets



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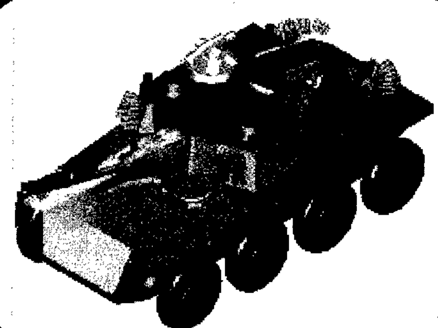
Future Vehicles Need Future Weapons

- Less armor and greater reliance on mobility, agility, and situational awareness
- Weapons requirements will change



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Guns Are Still Candidates

- Guns provide more stowed kills for short range targets
- Guns can provide flexible effects
  - Rate of fire
  - Choice of round

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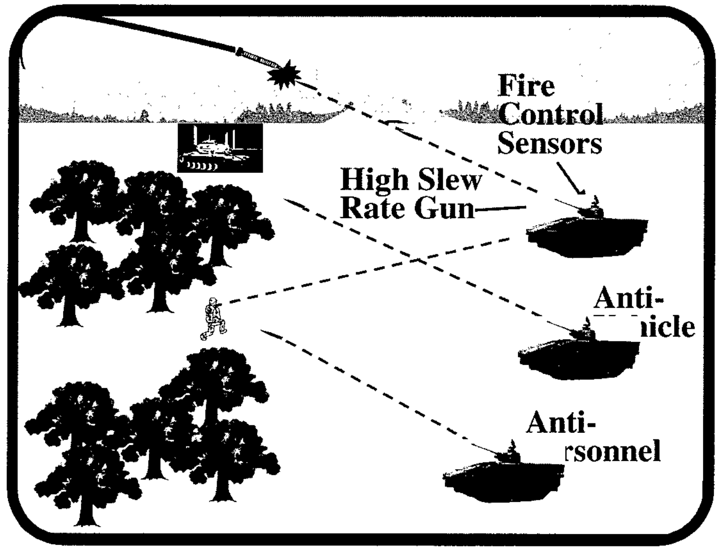
Missions

- Anti-vehicle
- Active protection
- Local air defense
- Anti-personnel
  - Lethal
  - Non-lethal

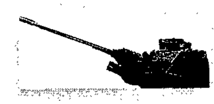


Gun Characteristics

- Agility
- Flexibility
- Accuracy
- Lethality
- Size, weight, power burdens

Existing Gun and Turret

Future Guns and Turrets



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Enabling Concepts

- Guided/smart munitions
- Agile gun carriage
- High speed breech mechanism
- Novel propellants/ electric guns

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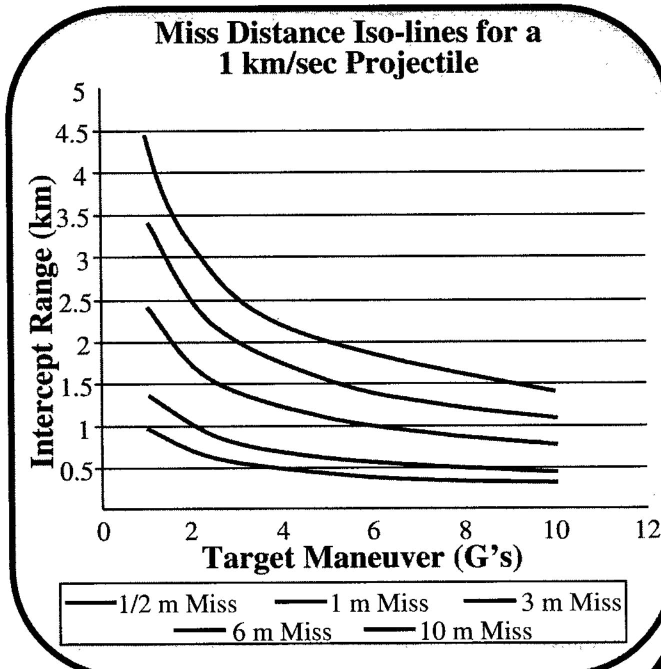
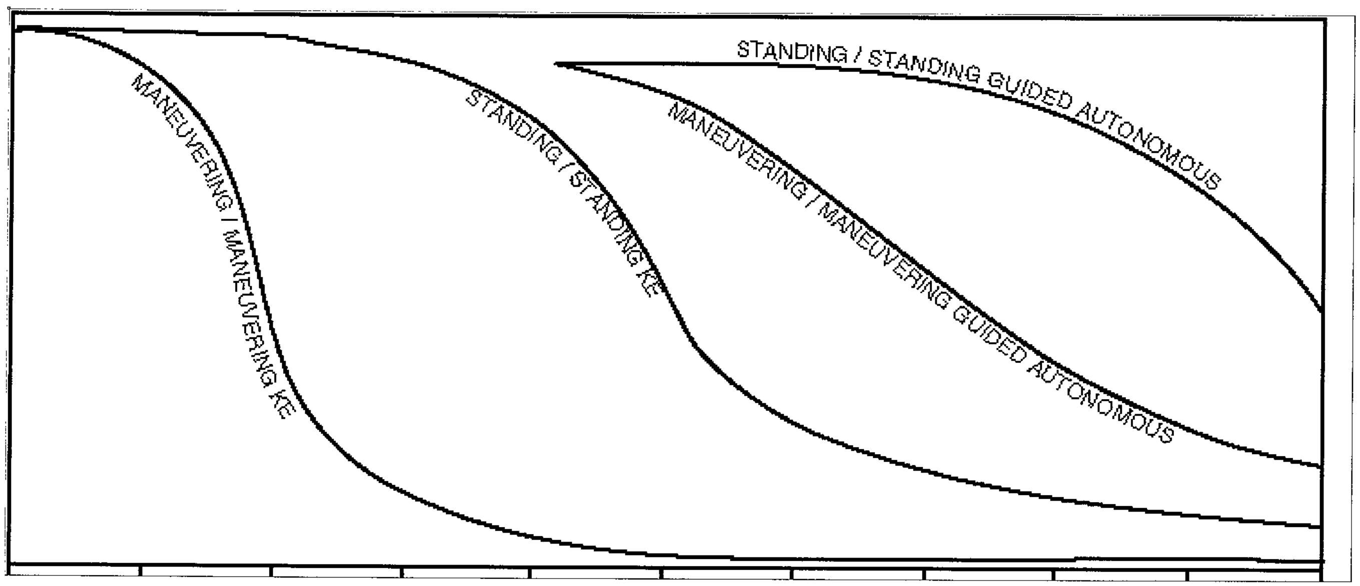
Why Smart Bullets ?

- Improved lethality with aimpoint selection
- Effective against maneuvering targets
- Novel effects with fused rounds



Example Payoff for Smart Bullets



	DOMINANCE IN:	
MODE OF ENGAGEMENT	RANGE	BATTLESPACE
STANDING–STANDING	2:1	4:1
MANEUVERING–MANEUVERING	3.5:1	12+:1

LEGEND:

- KE BALLISTIC
- KE, GUIDED AUTONOMOUS

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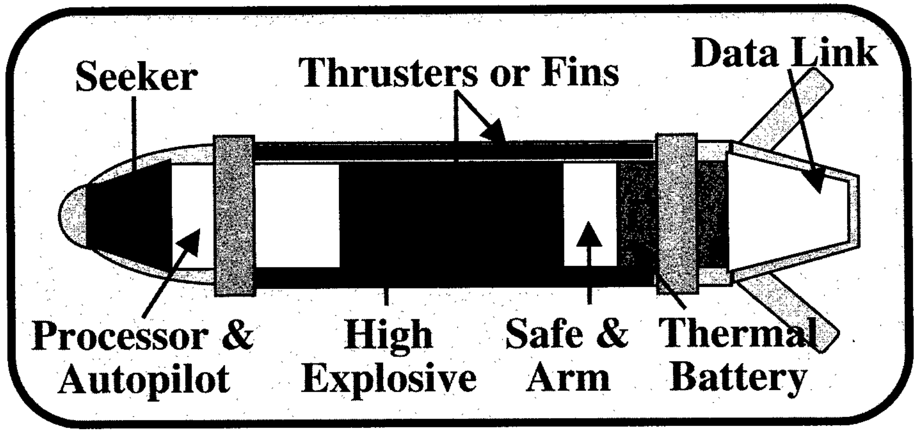
Key Technologies

- Guidance approach
- Sensors
  - –IMU's
  - –Seekers
- Divert
  - –Propulsive divert
  - –Aero conrol
- Fuse and Warhead



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Additional Challenges

- Cost: \$100 – \$1000 per round
- Launch Environment
  - 10 to 100 kilo-Gs
  - High Radial Gs
- Packaging Volume: ~1 – 10 cm^3

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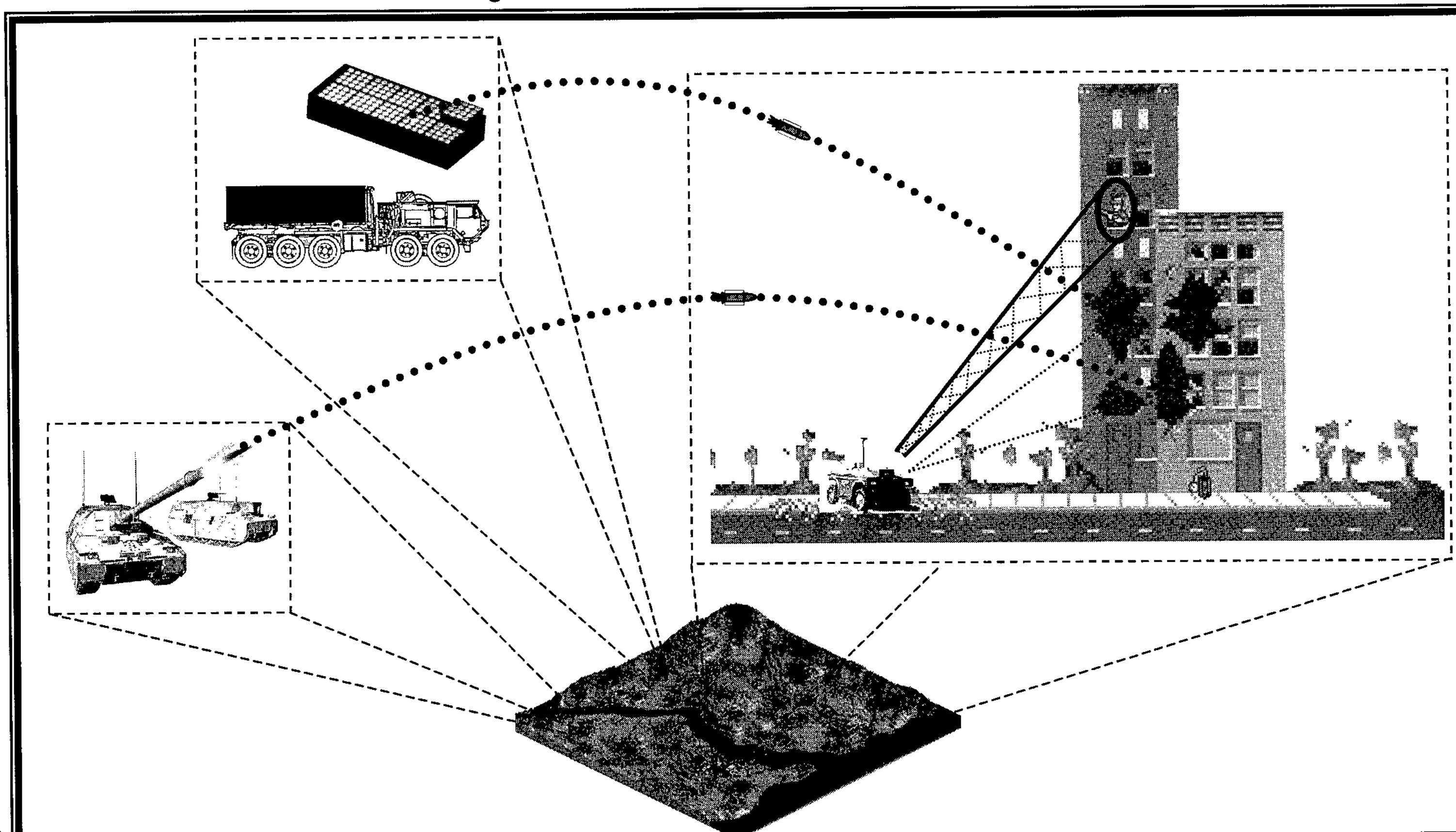
Current Activities

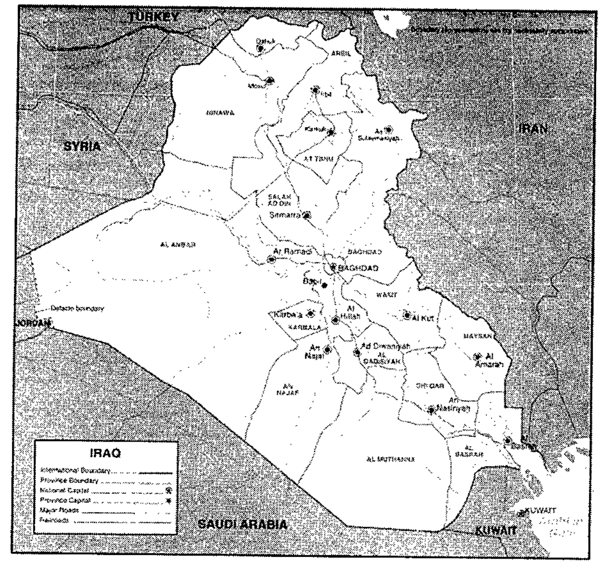
- DARPA is looking for high payoff concepts around which to base a new program.
- Can accept white papers/proposals under open BAA 98-35
- Government led studies are examining operational benefits of smart bullets and other future gun concepts.

Multi-Mission Combat Systems

Dr. Marilyn Freeman, DARPA TTO



The Past - Desert Storm



- 525,000 US troops deployed
- 7 month deployment period via ships and air
- Strategic Airlift:
  - 4.65 billion ton-miles (697.5 million for Berlin Airlift)
  - 20,500 missions; 534,000 passengers; 542,000 tons
- Ground Forces Example - VII Corps Support:
  - 150,000 troops, 50,000 combat vehicles
  - Estimated 800,000 gallons diesel/day consumption
  - Required 3,300,000 gallons diesel/day (11,500 tons)

The Present - Kosovo

- Quick reaction desired → rapid deployment

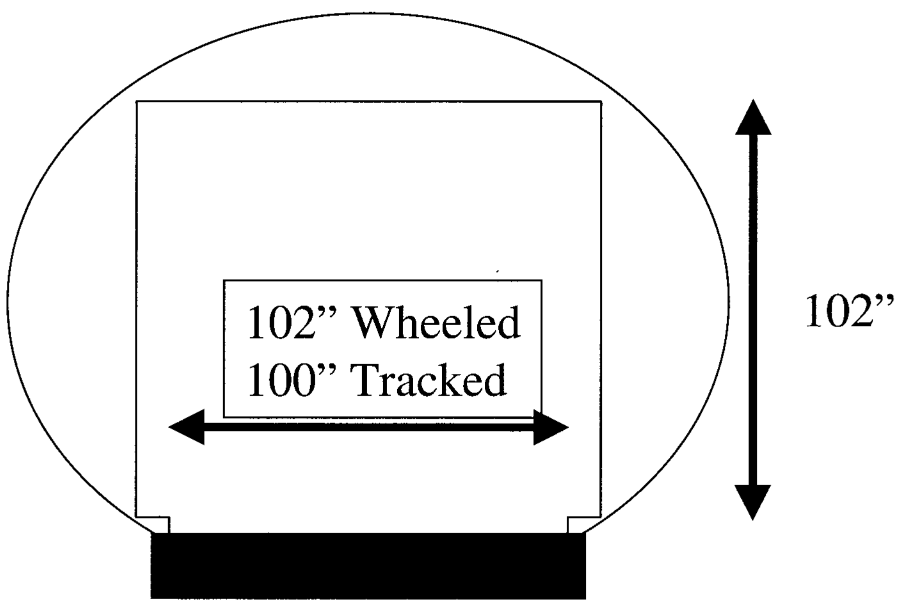
- Mission / Force Option/ Estimates
  - 8,000 troops to secure border
  - 75,000 troops to liberate Kosovo
  - 200,000 troops to occupy and monitor

- Troop transport - not the hard part
  - 240,000 troops to Desert Shield in 1 month
  - Vehicles & support not available for <u>many</u> weeks

- Full Deployment Options
  - Rapid Reaction → Air Transport
  - Tactical Insertion → C-130/C-17
  - Urgency Rules Out Strategic Sea lift

Deployability & Transportability Challenges

C-130J Size Limitations



C-130J: 36,000-40,000 lb Payload Capacity

M2/M3 Bradley

117”

126”
50,000 lb Combat Weight

FCS

105”

102”
36,000 lb Combat Weight

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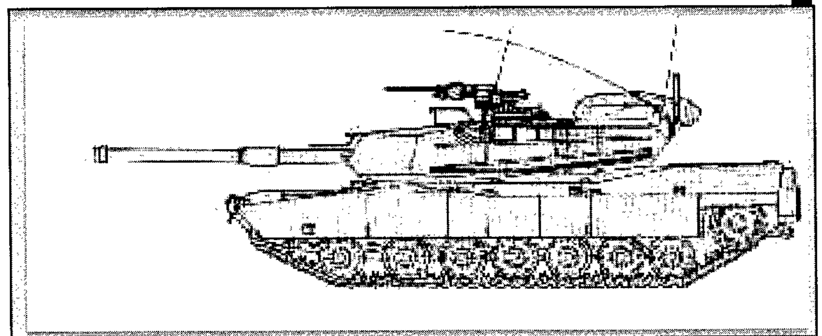
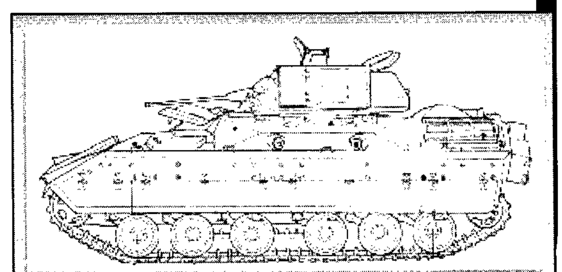
Design Drivers

- Weight
  - 40%-50% of manned combat vehicle weight is armor
  - 20% is weapons system
  - 20% is drive train



- Size
  - Vehicle height is determined by human factors
    - › M1 A1 Abrams - 3.25 ft. height for reclined driver
    - › M3 Bradley - > 4 ft. for seated troops
  - Width
    - › Maximums are transportability related
    - › Minimums are subsystem spacing or human factors related



  - Volume (MBT)
    - › Approximately 30% of volume is attributed to crew

The Future - Army After Next

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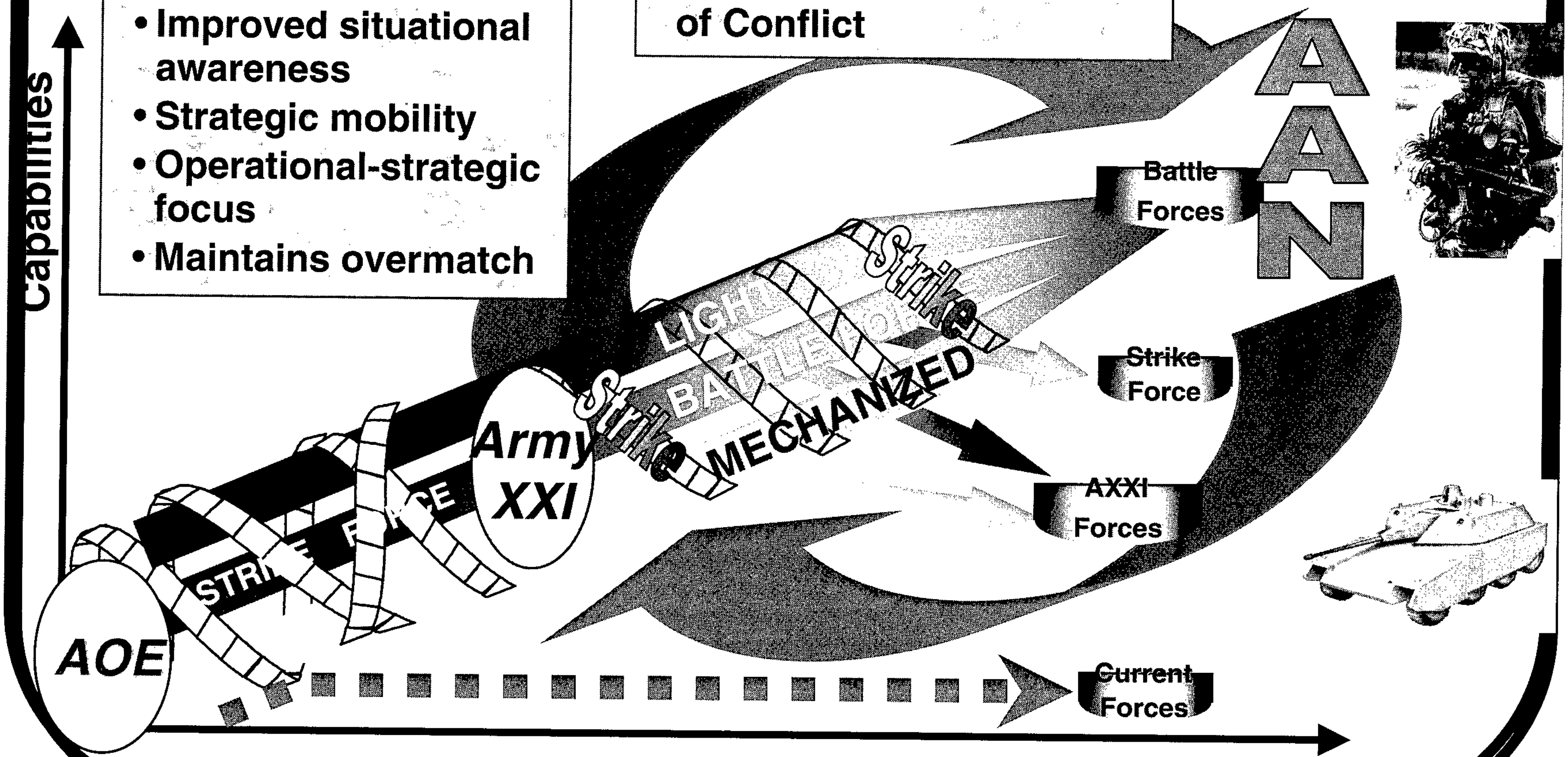
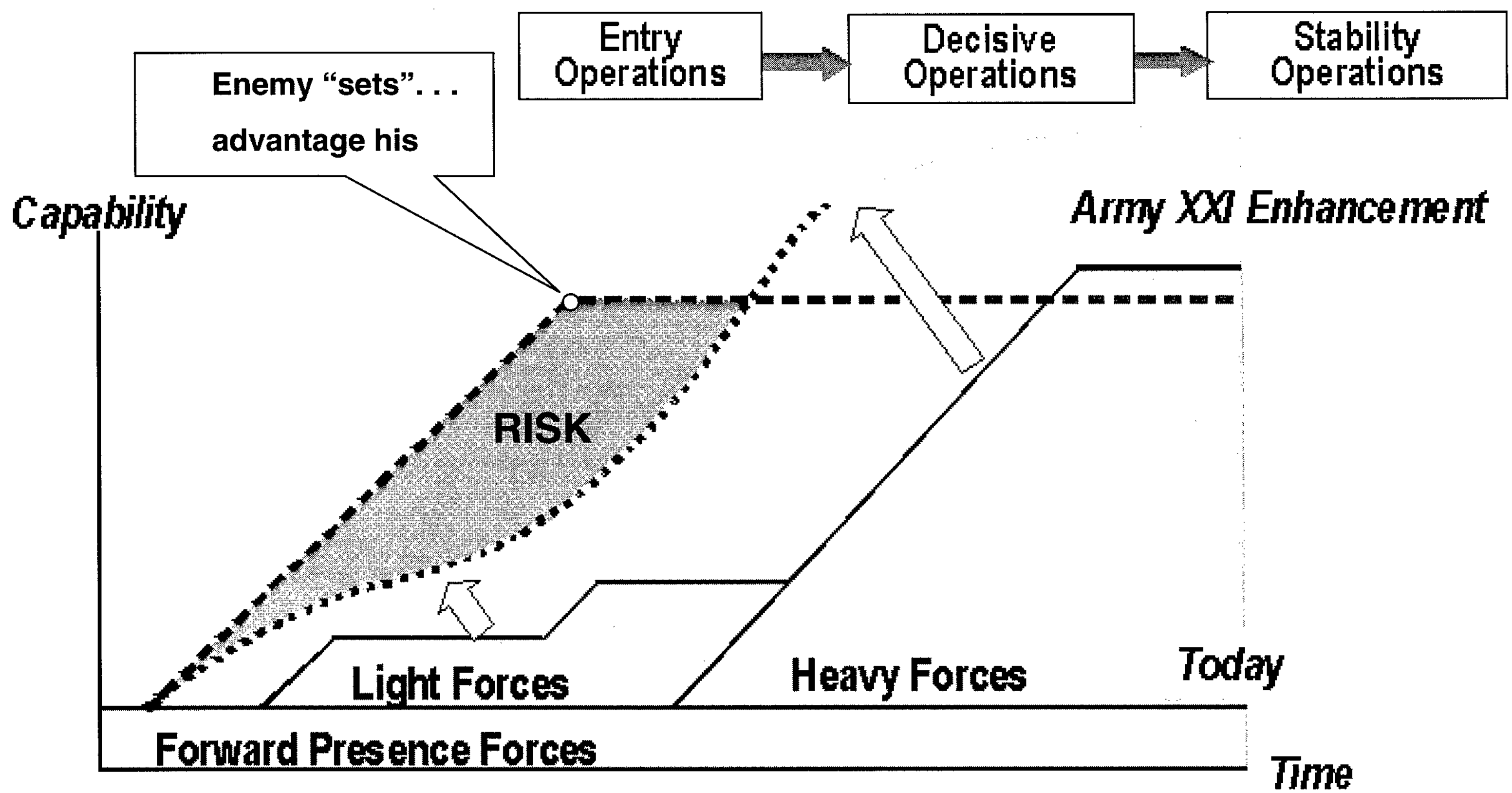
- Information Dominance
- Global Maneuver
- Regional Engagement
- Dominates Full Spectrum of Conflict

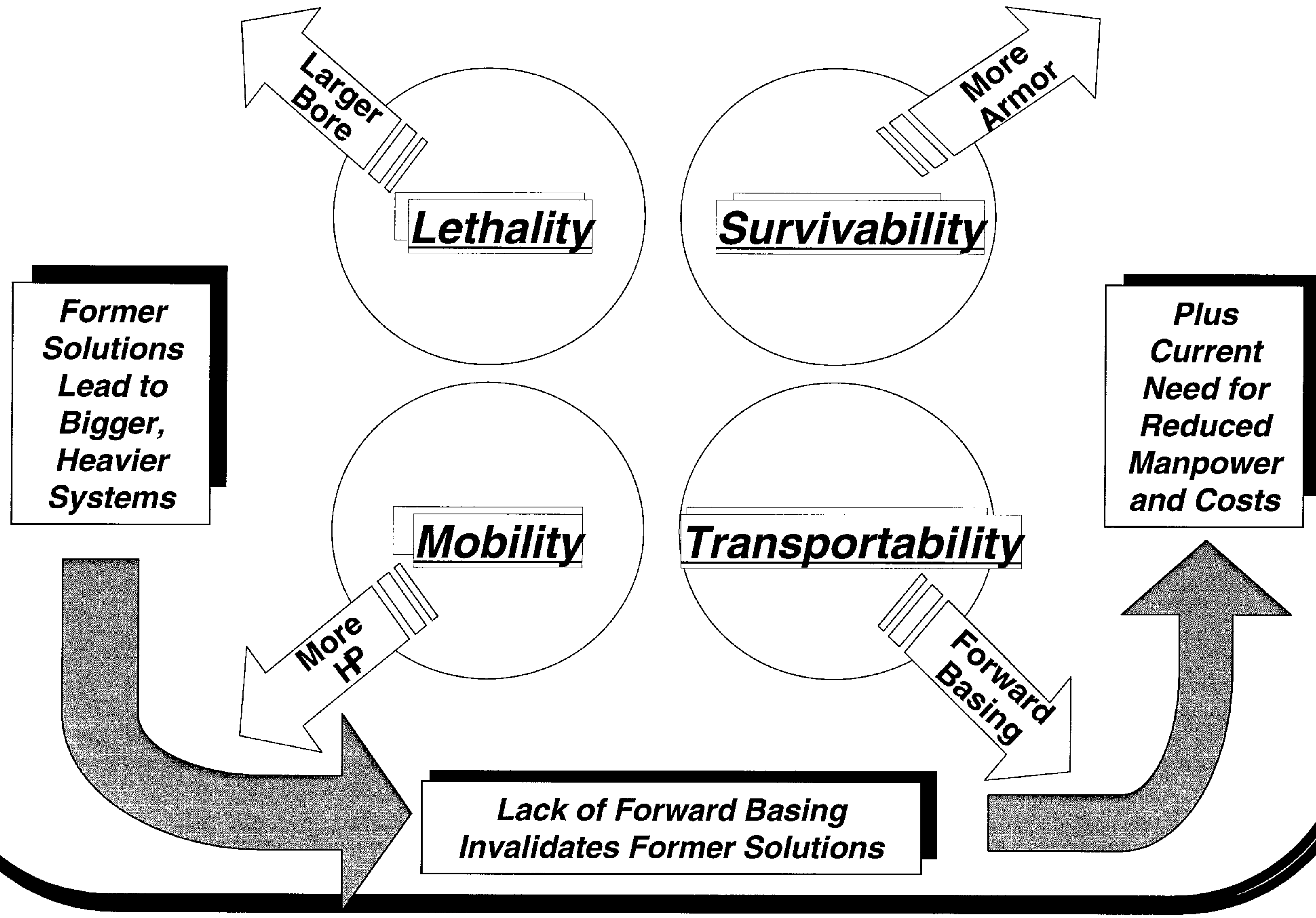
- Improved situational awareness
- Strategic mobility
- Operational-strategic focus
- Maintains overmatch



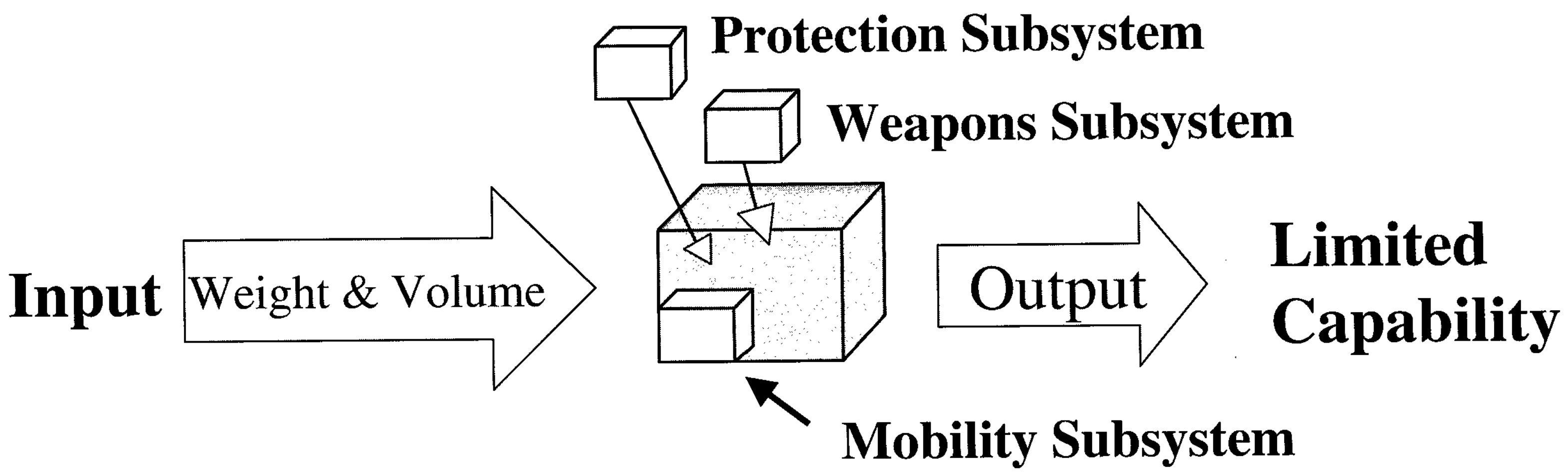
What Are We Trying to Fix?

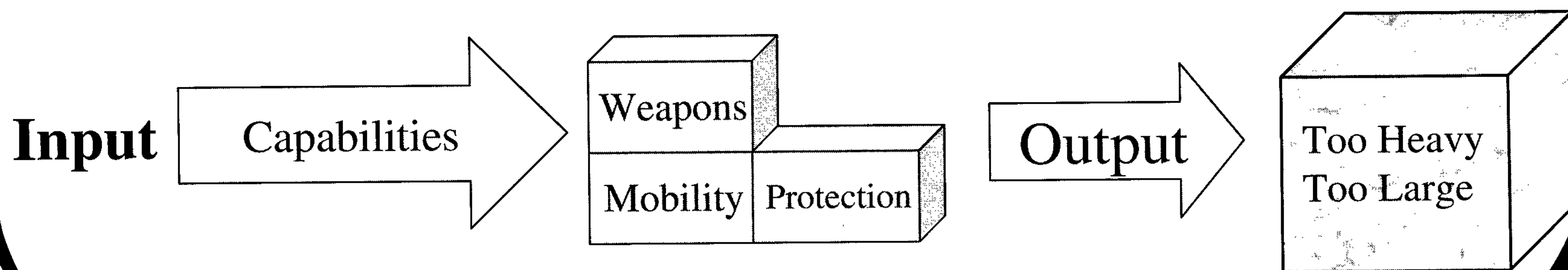


What Limits Past Solutions?

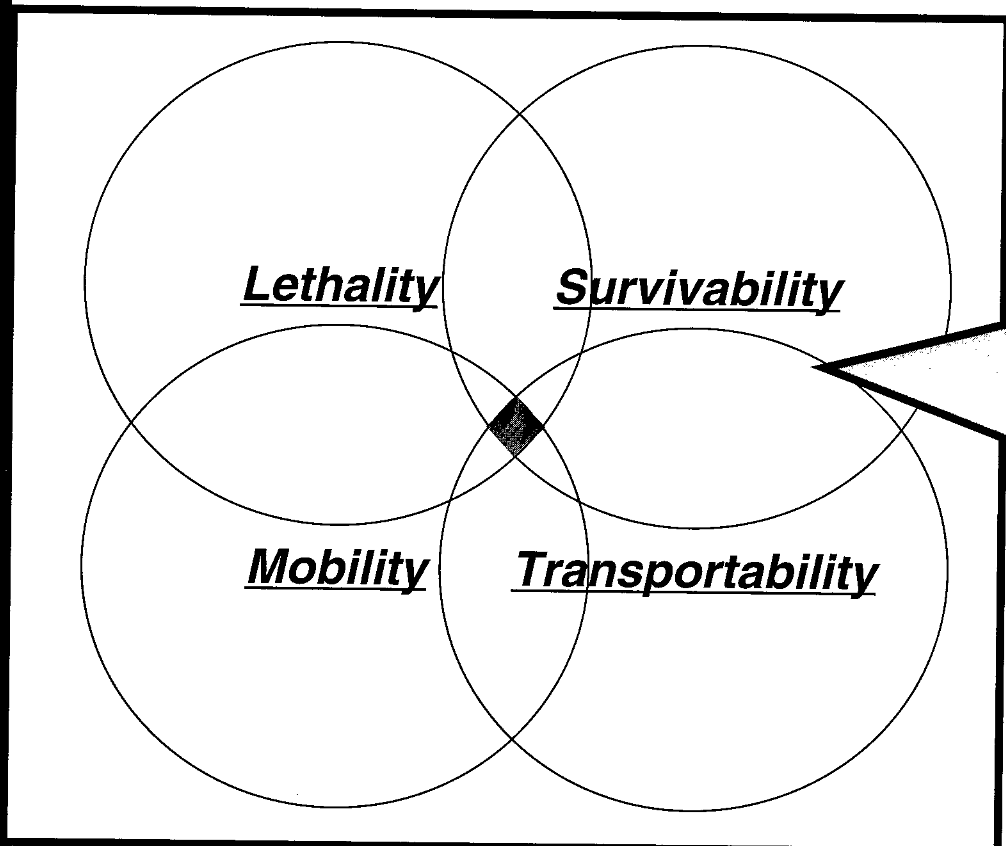


Current Design Approaches





Multi-Mission Combat Systems - A New Approach



Common Solutions

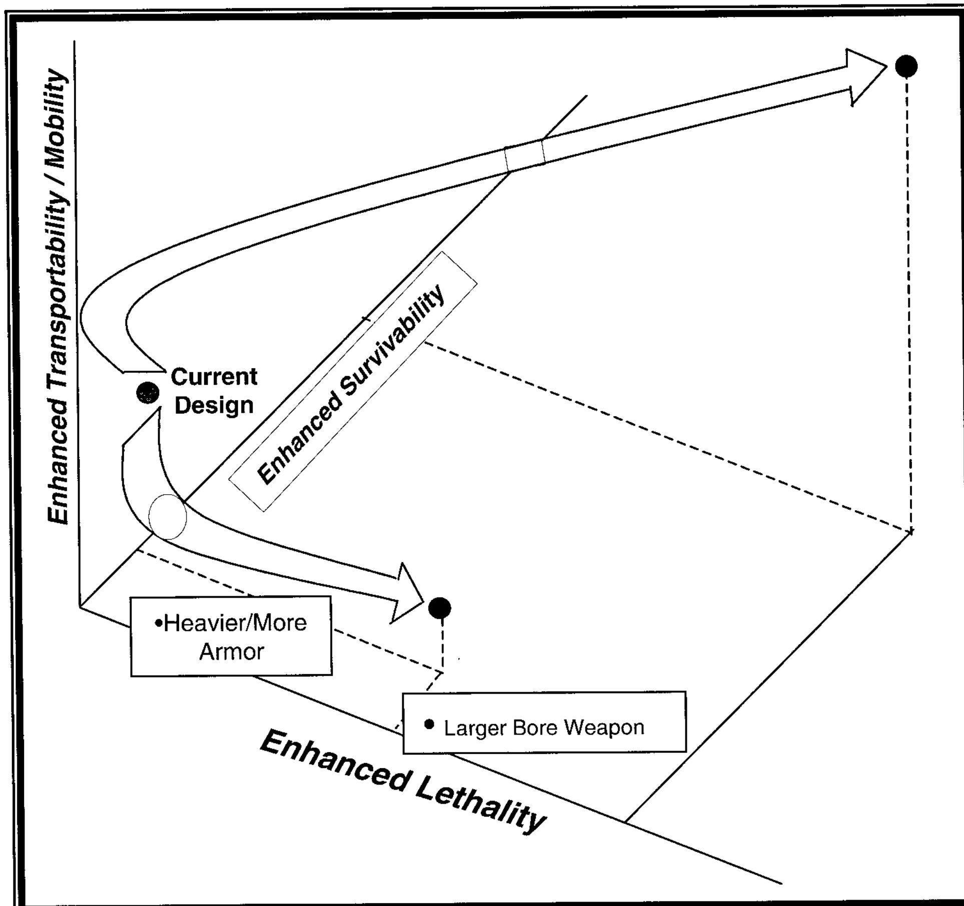
- Reduced Size
- Stealth
- Reduce/Eliminate Crew

Technologies

- Robotics
- Electric Propulsion
- Adv Lethality
- Active Protection

DARPA/Army Study Goals

- Identify potential solutions and new approaches
- Provide convincing data supporting high payoff
- Explore and demonstrate high risk solutions and/or novel approaches to ground combat



Total Systems Approach Is Needed

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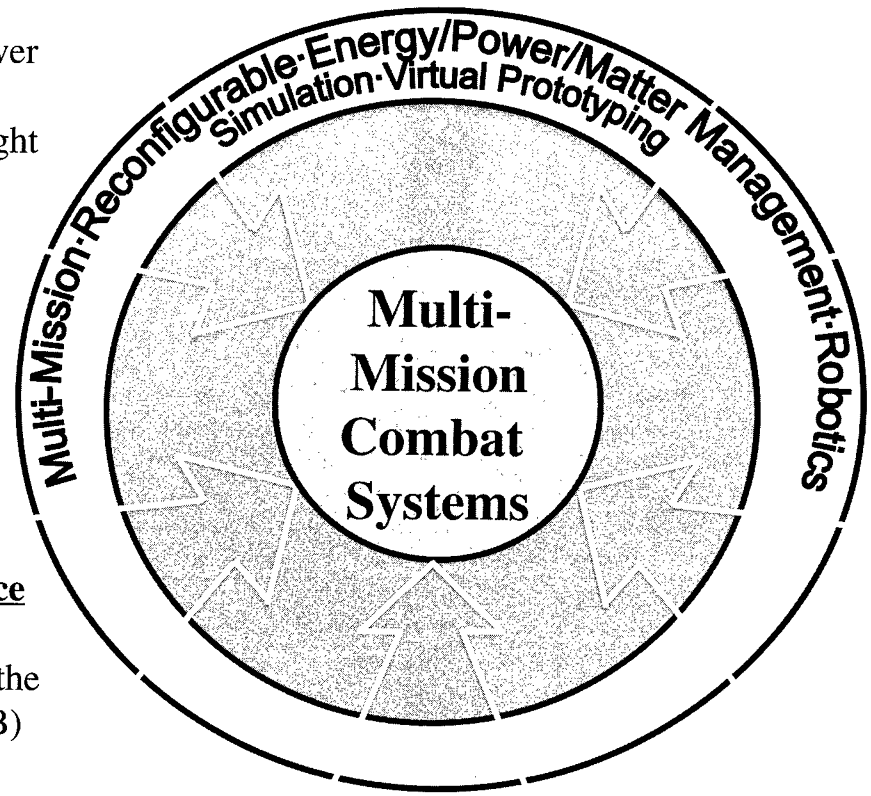
New Design Philosophy

Mobility/ Transportibility
- Common Prime Power
- All-Wheel Drive
- Advanced Lightweight Materials

Lethality
- Energy Sources
- Launchers
- Missiles
- Smart Munitions

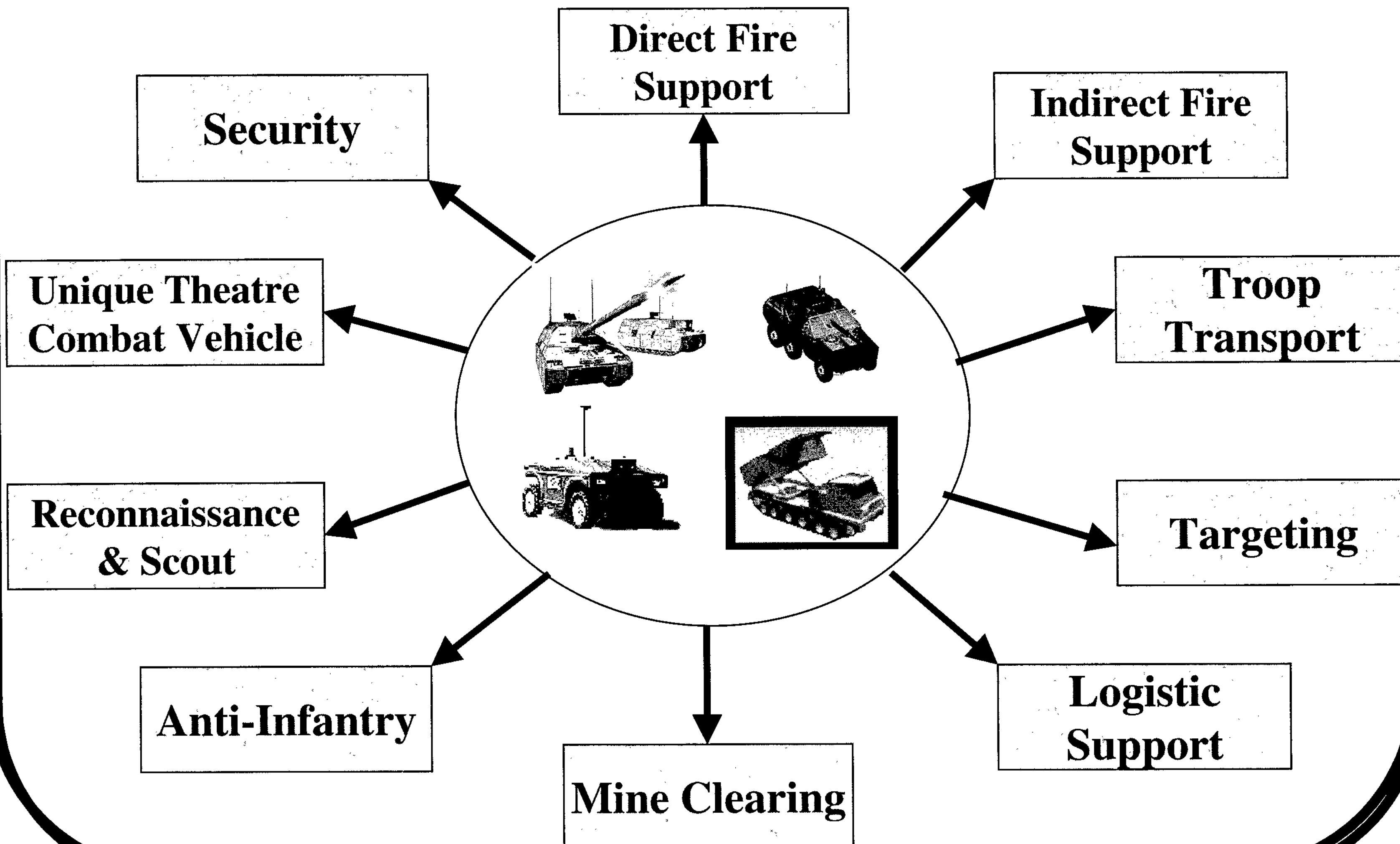


Information Dominance
- Intelligence Preparation of the Battlefield (IPB)
- Situational Awareness

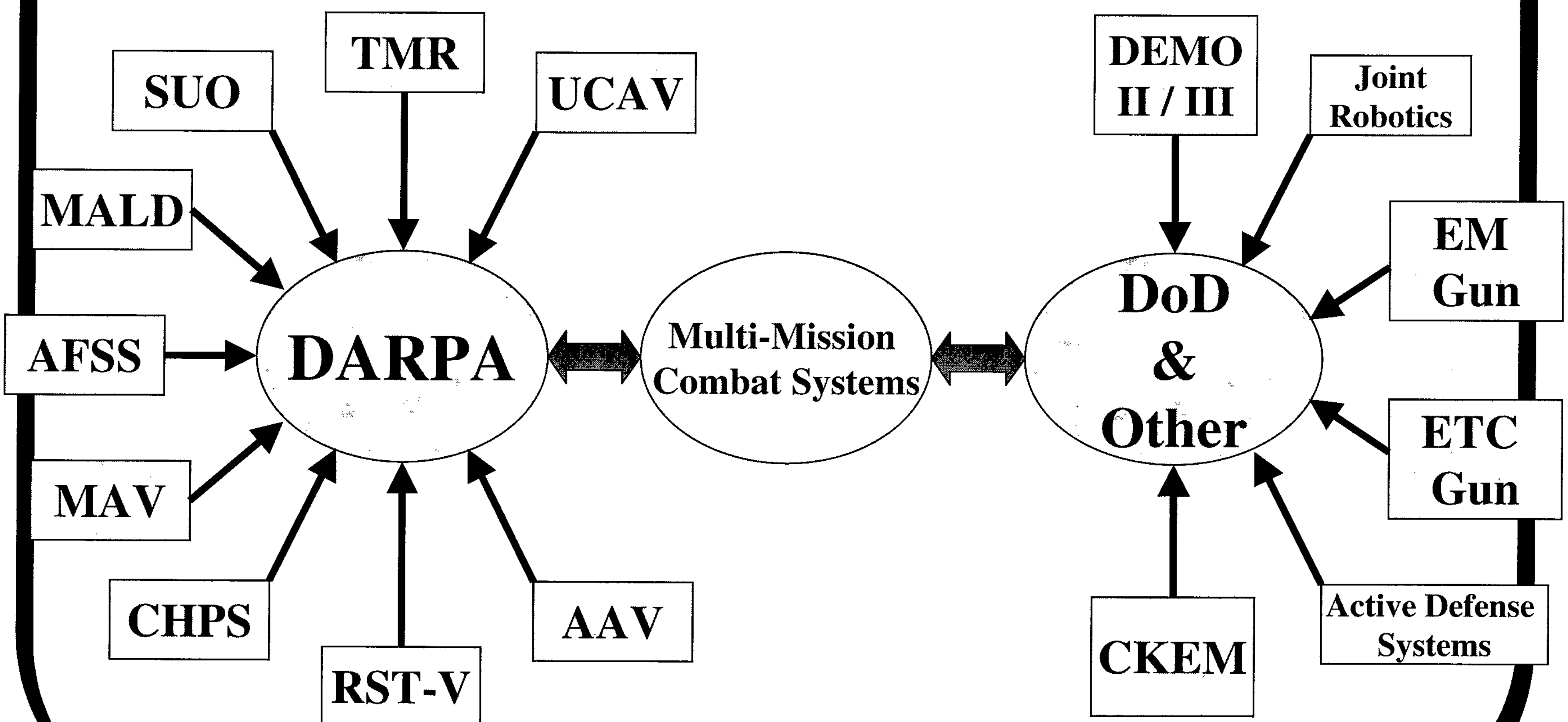
Survivability
- Active Defense
- Passive Defense
- Threat Avoidance
- Minimally Manned Systems

Supportability
- Reduced Fuel Dependence
- Reduced Maintenance
- Reduced Life Cycle Costs

Multi-Mission Systems



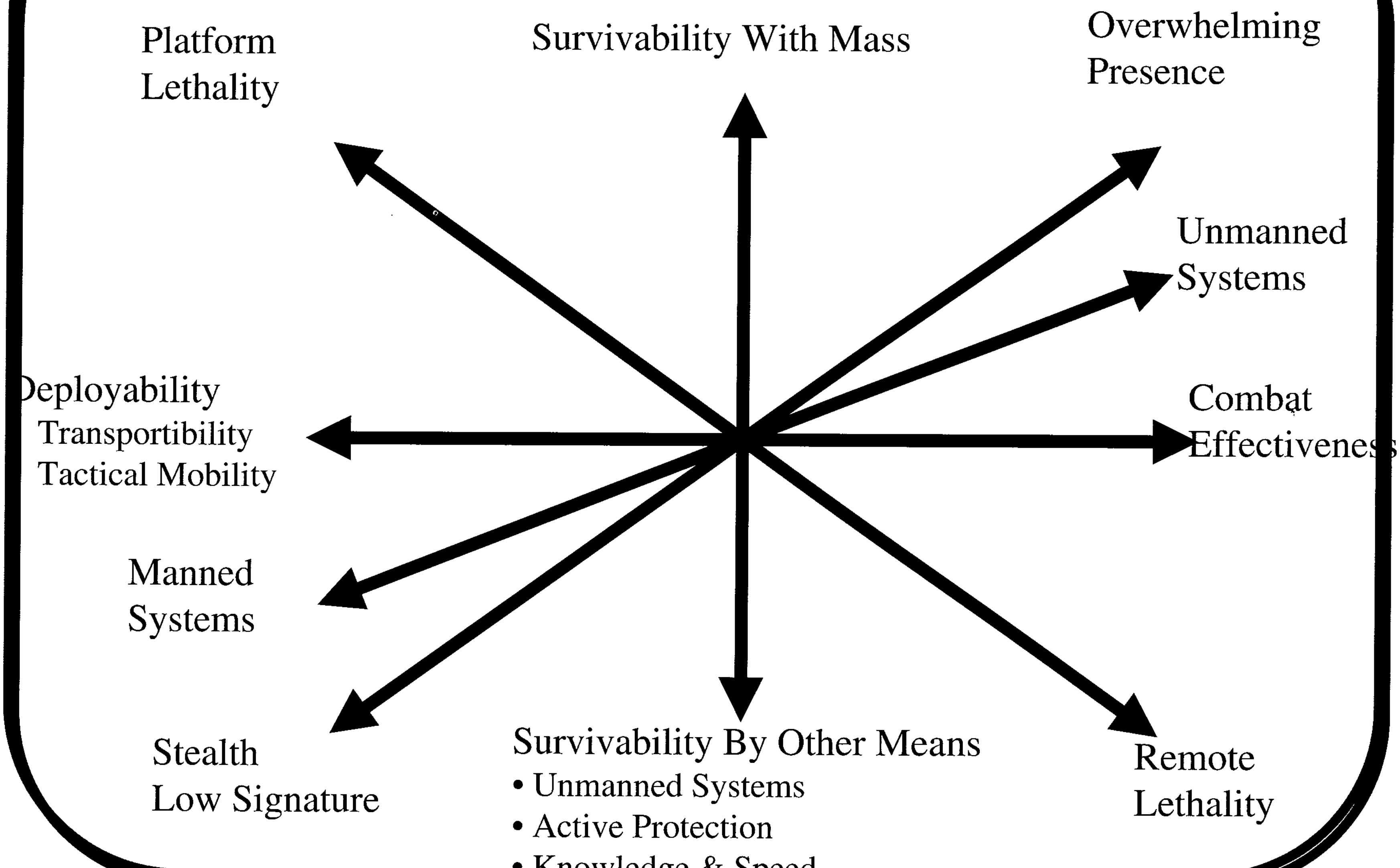
Technologies & Concepts From Existing Programs



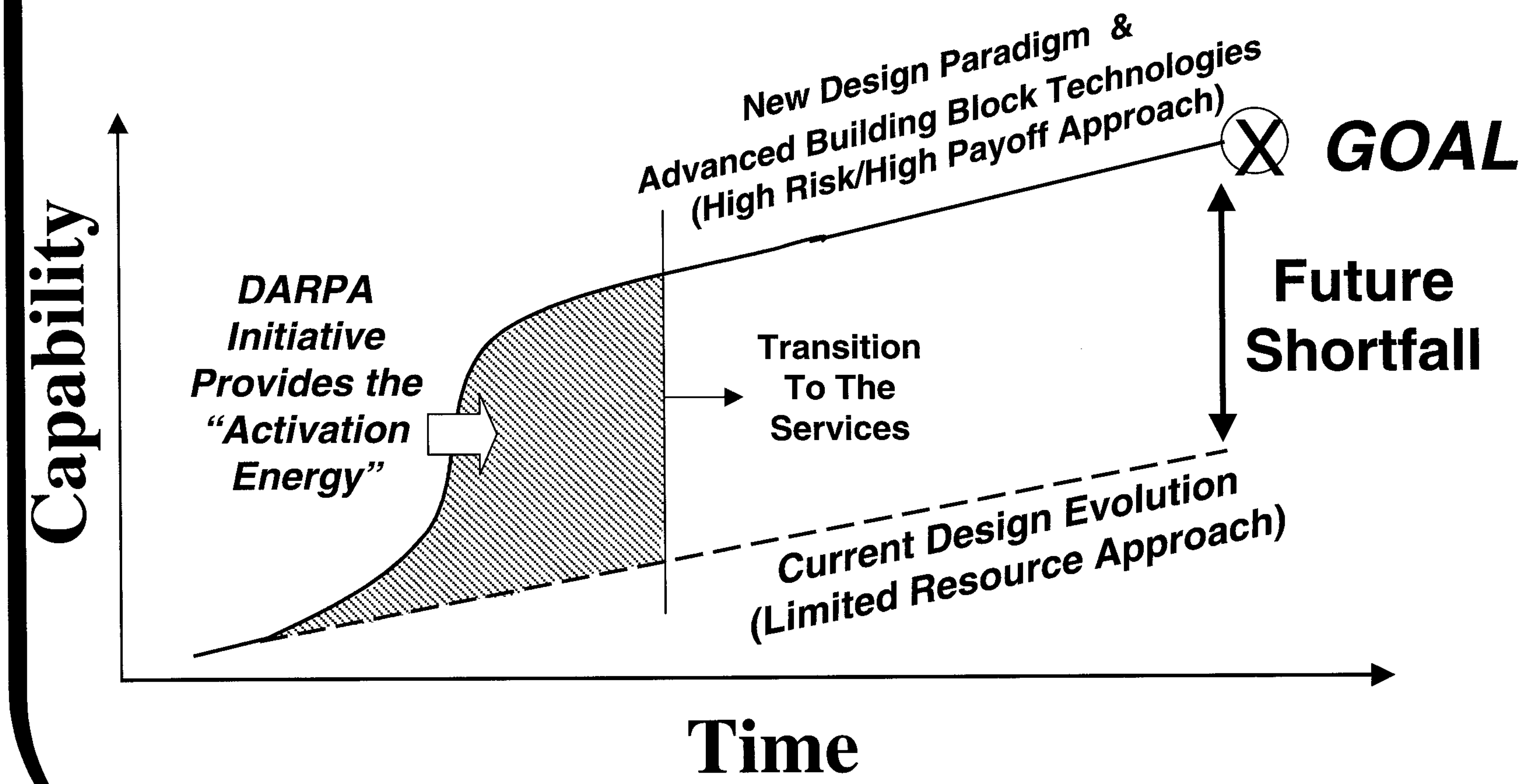
DARPA/Army Study Concept

- Use total systems approach for Multi-Mission Combat Systems:
  - Multi-functional/multi-mission capabilities
  - Re-configurable systems
  - Enhanced survivability through manned/ unmanned teaming, active defense, etc.
  - Enhanced lethality/mission effectiveness
  - Enhanced situational awareness
  - Energy and power management with multi-function components

Study Azimuths



DARPA Role


Capability
Time
DARPA Initiative Provides the "Activation Energy"
New Design Paradigm &
Advanced Building Block Technologies
(High Risk/High Payoff Approach)
GOAL
Transition To The Services
Future Shortfall
Current Design Evolution
(Limited Resource Approach)

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Study Program Plan

- Identify high risk/high payoff concepts
- Identify issues with manned/unmanned teaming, advanced weapons systems
- Assess systems capabilities against appropriate missions
- Identify existing program crossovers
- Identify enabling technologies

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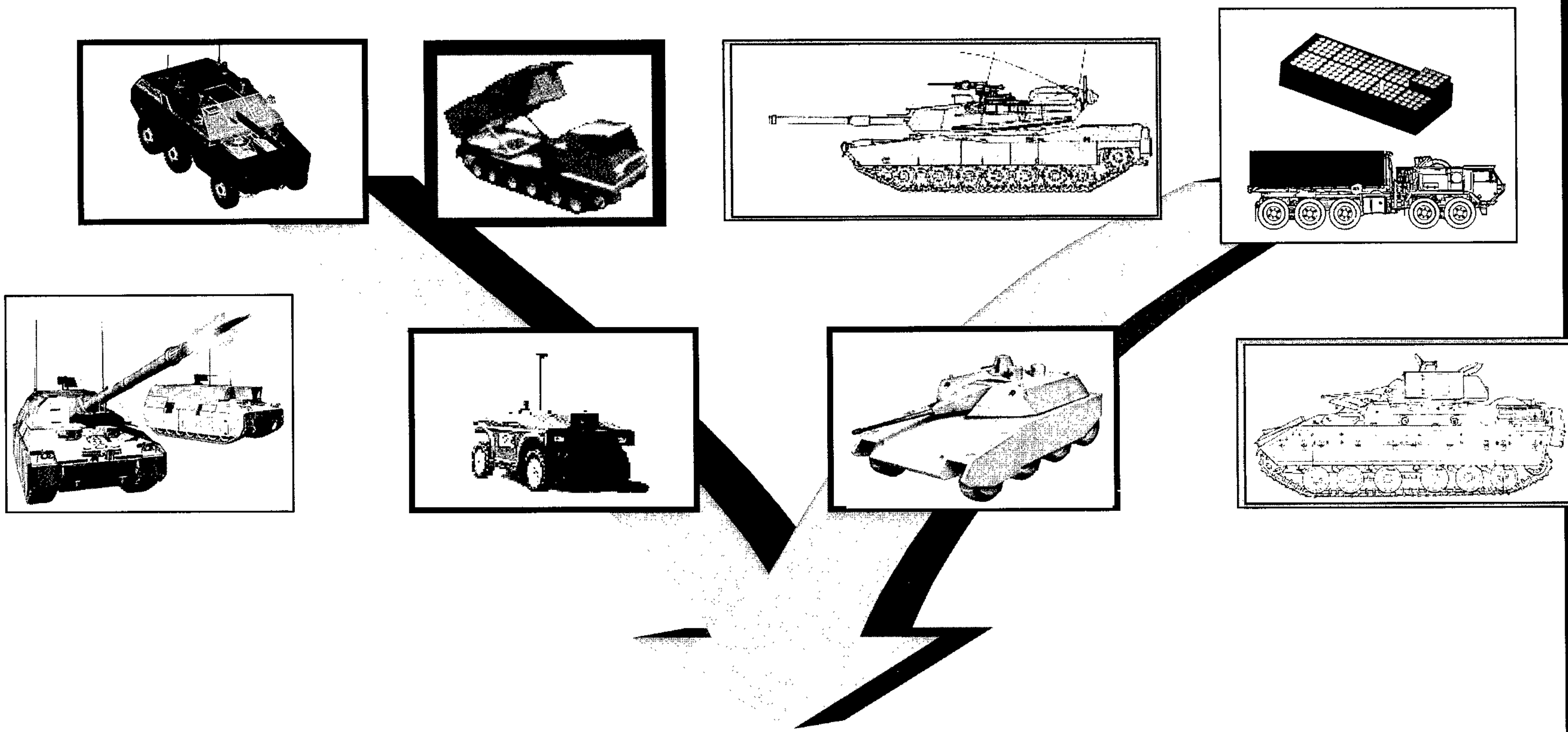

Multi-Mission Combat Systems

DARPA ATO

DARPATech '99

Advanced Technology Office

Dr. Tom Meyer
Director, ATO

June 1999

DARPA ATO

Focus Areas

- Communications
- Maritime
- Early Entry / Special Operations

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People

Name	Phone	Name	Phone
Tom Meyer	703-696-2297	Joe Mitola	703-248-1515
William Jeffrey	703-696-2315	Art Morrish	703-696-7502
Tom Altshuler	703-696-0222	Frank Patten	703-696-2285
John Blitch	703-696-4464	John Polcari	703-696-2313
Ed Carapezza	703-696-2317	Gladys Reichlen	703-248-1516
Regina Dugan	703-696-2296	Rick Ridgley	703-248-1517
Theo Kooij	703-696-2333	Rob Ruth	703-696-2260
Mark McHenry	703-696-7495	Norm Whitaker	703-696-7501
Stu Milner	703-696-7449		

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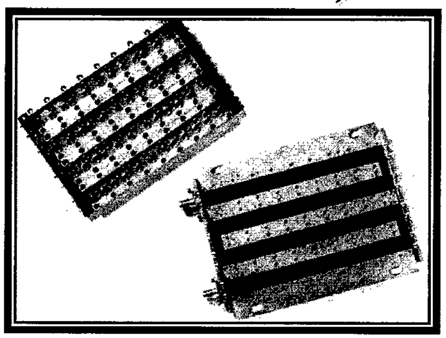
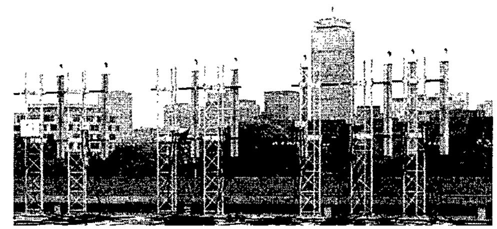
Communications

HTS Filters, LNA

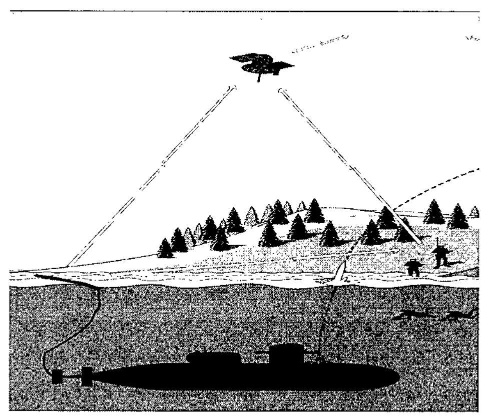


Network/Comms Node



Innovative Antennas

Complex Nets



Sub Comms

+ S/W Radios

+ Advanced Waveforms

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Comms Challenges

- Agile spectrum management
- Assured access
- Autonomous, self-organizing wireless networks
- Robust to stressing environment and loss of components
- Multi-level secure

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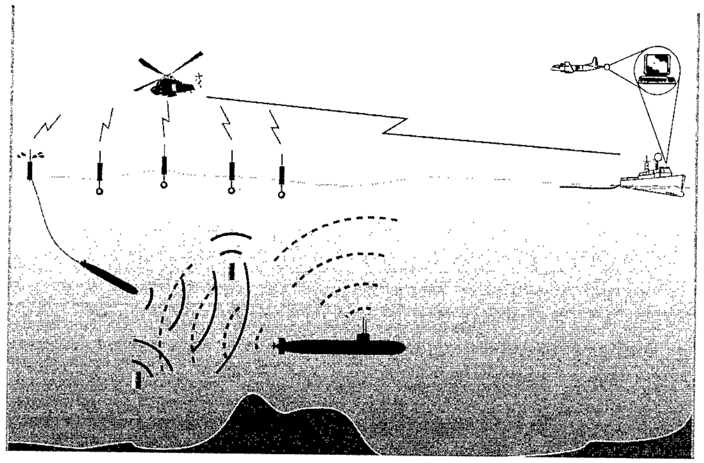
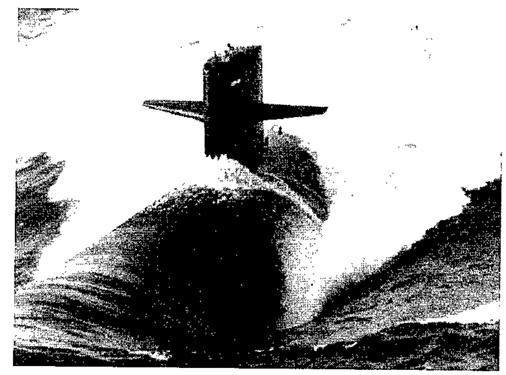
Maritime

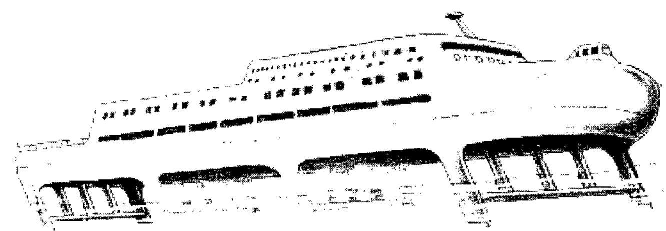


Netted Acquisition and Targeting

New Missions



Advanced Platforms



Antimine

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Maritime Challenges

- Evolving roles and missions
- Fast transport (end-to-end)
- Optimal platform design
- Underwater power sources
- Wide area subsurface mapping

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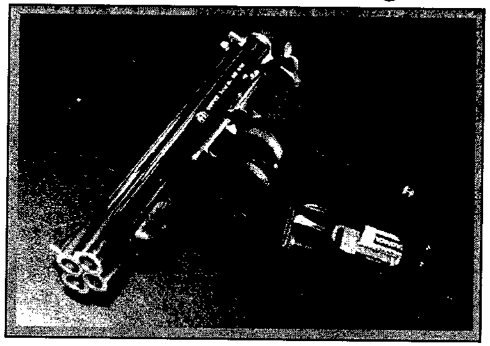
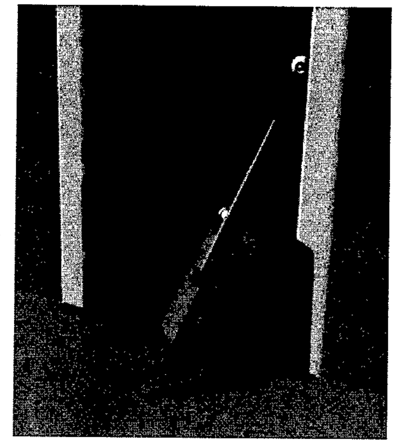
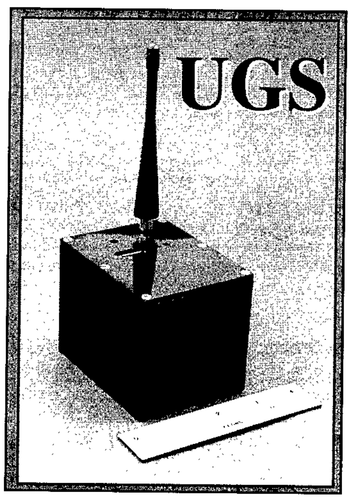
Early Entry/Special Ops



Weapons

Robotics





UXO

+ Self-Healing Mine Fields

+ Warfighter Visualization

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Challenges

- Rapidly deployable, lethal, and survivable with global reach
- Situational awareness at the lowest echelons
- Enhanced unmanned capability

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Opportunity

- New Office / New Focus
- Looking for *great* ideas
- Looking for *great* people
- Look to web page for details on upcoming BAAs

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Mine Detection and Alternatives to Antipersonnel Landmines

Thomas W. Altshuler
taltshuler@darpa.mil

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The Programs

- Electronic Dog's Nose

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DARPA ATO

The Programs

- Self-Healing Minefield
- Tags and Minimally Guided Munitions

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Antipersonnel Landmine Debate

Challenge is finding creative technology solutions in this highly constrained environment

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The DARPA Approach

- Innovative maneuver denial approaches
  - Employ advanced technologies
  - Provide increased warfighting capability

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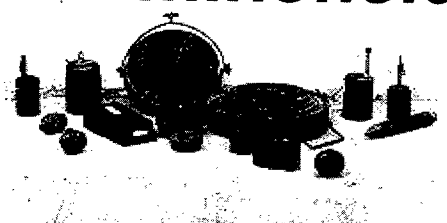
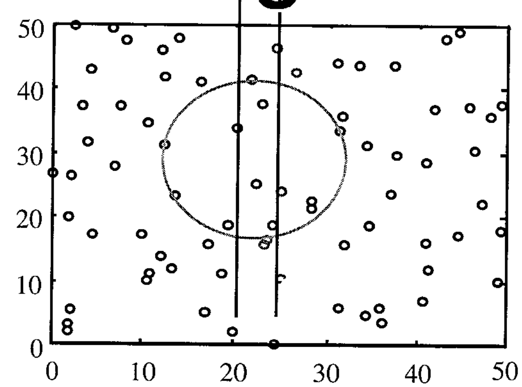
Two Innovative Approaches

Mixed Munitions

Protection of AT minefields

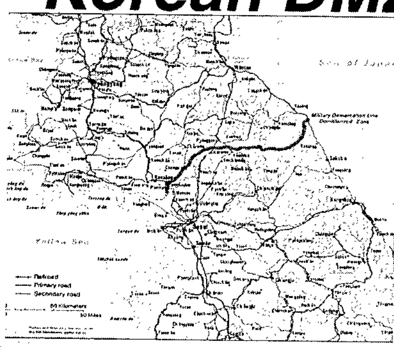


Self-Healing Minefield



Dismounted Infantry

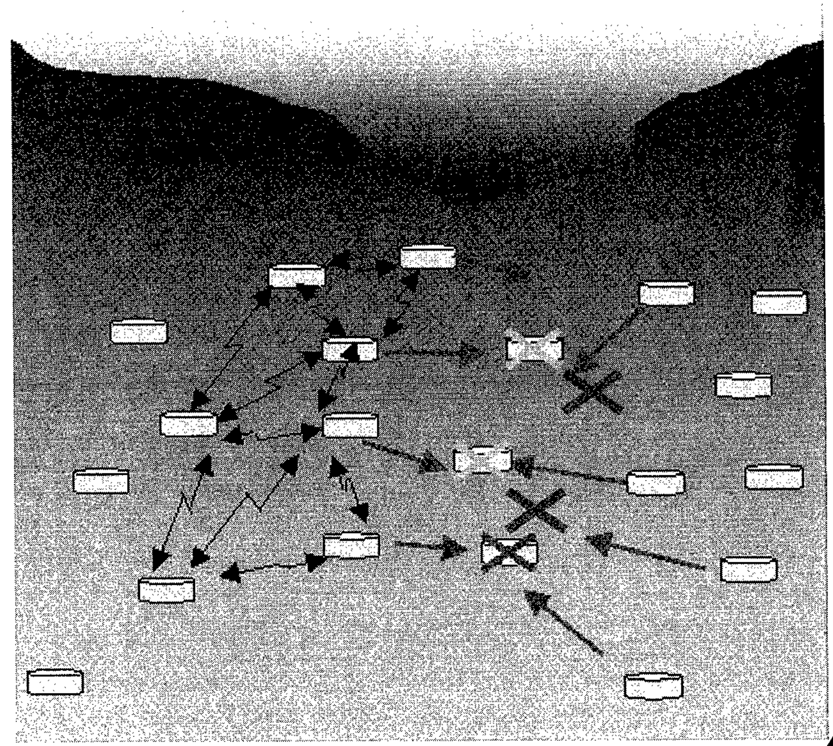
Korean DMZ



Tags/MGM

Self-Healing Minefield

Dynamic antitank minefield used to complicate breaching and preserve the obstacle



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Operational Concept

- Scatterable surface antitank mines
- Minefield detects breach
- Individual mines reorganize to defeat breach

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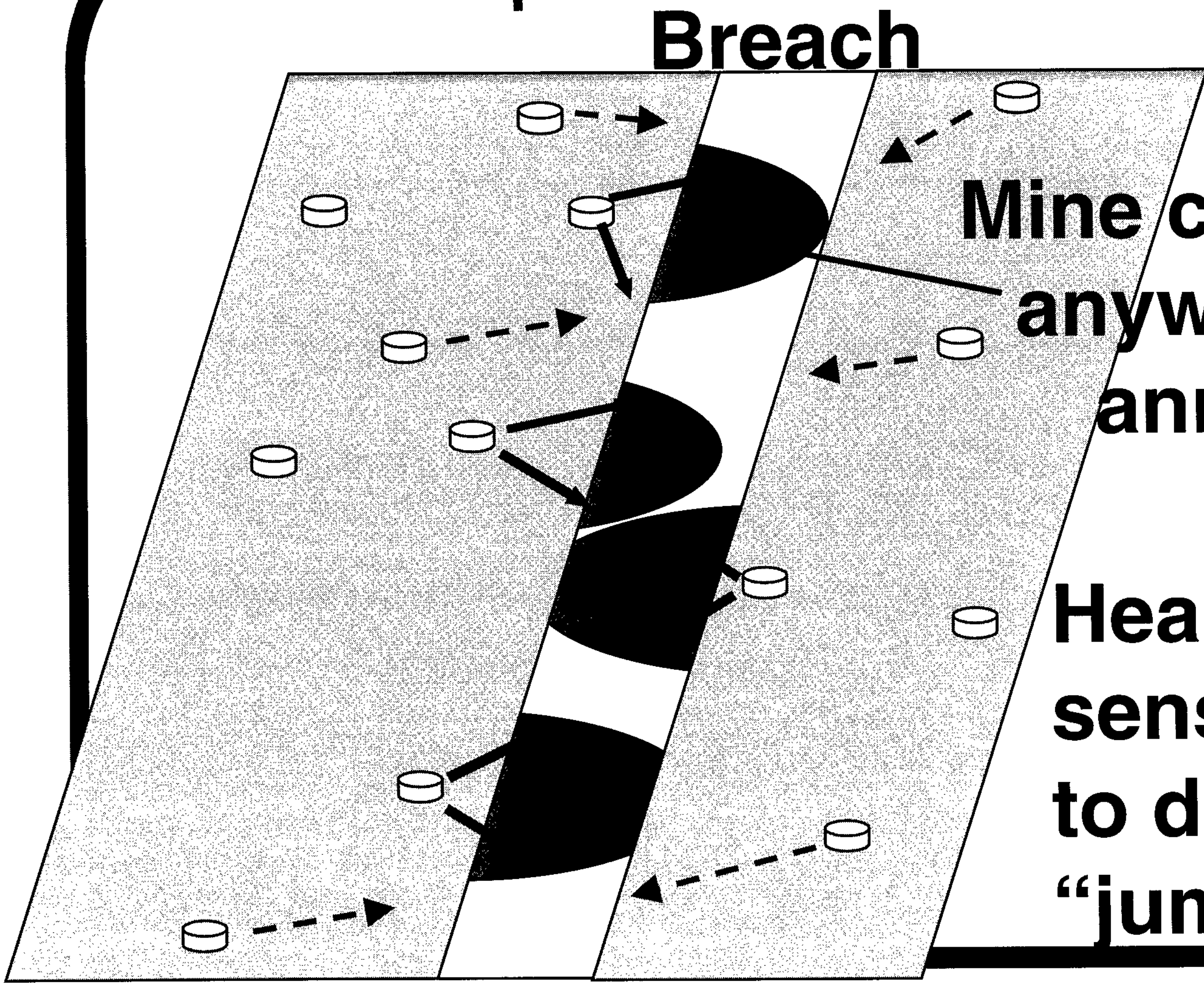
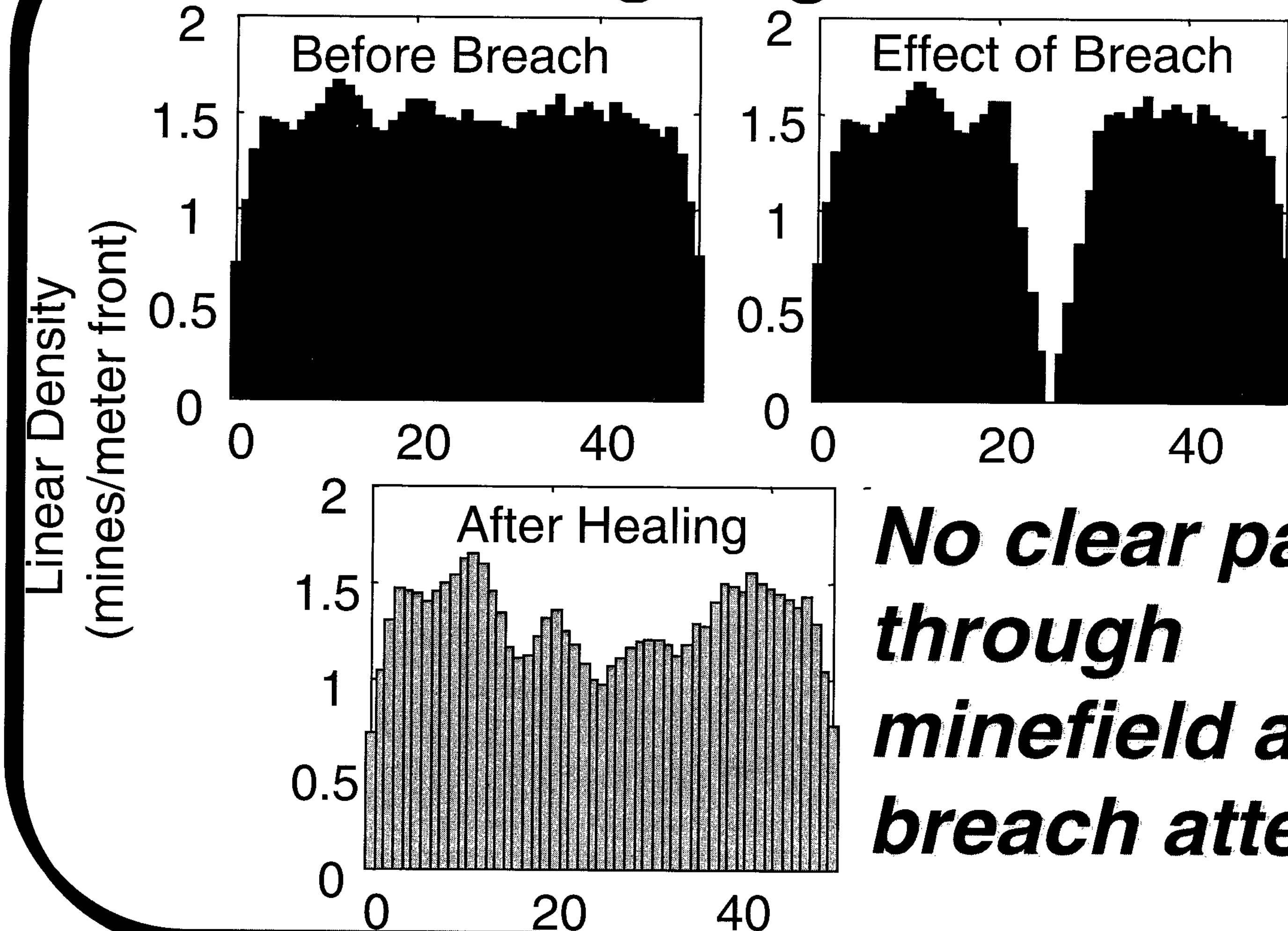
Response to Breach



- Mine can move anywhere in annulus
- Healing not sensitive to details of "jump"

Healing Algorithms



No clear path through minefield after breach attempt

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Mine Mobility

- Healing is a statistical process
- Simple mobility needed
- Will be fault tolerant
- NO COMPLEX ROBOTICS

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System Benefits

- Prevents/impedes breach without antipersonnel landmines
- Opportunity for control of minefield
- Enemy must clear minefield

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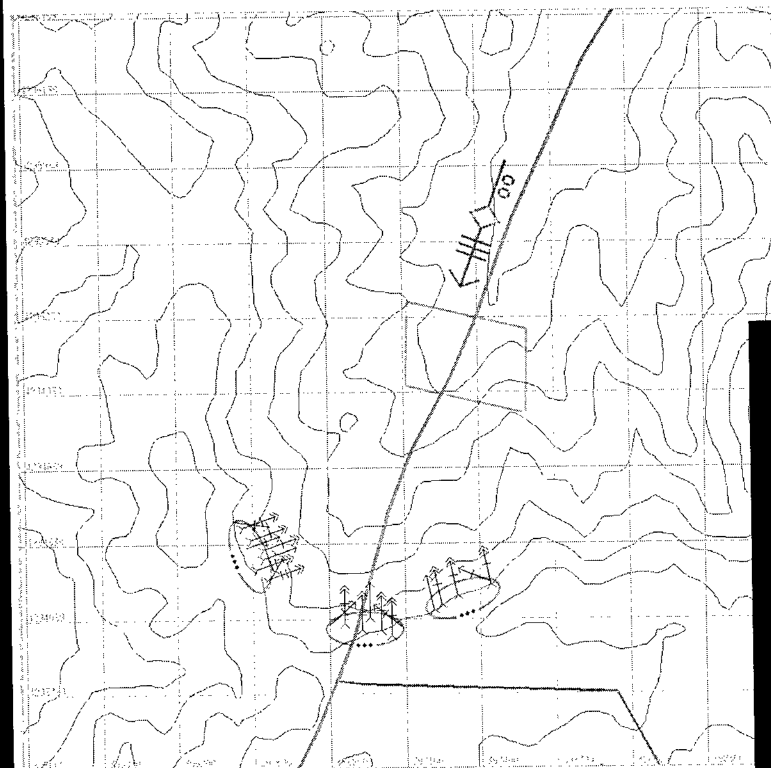
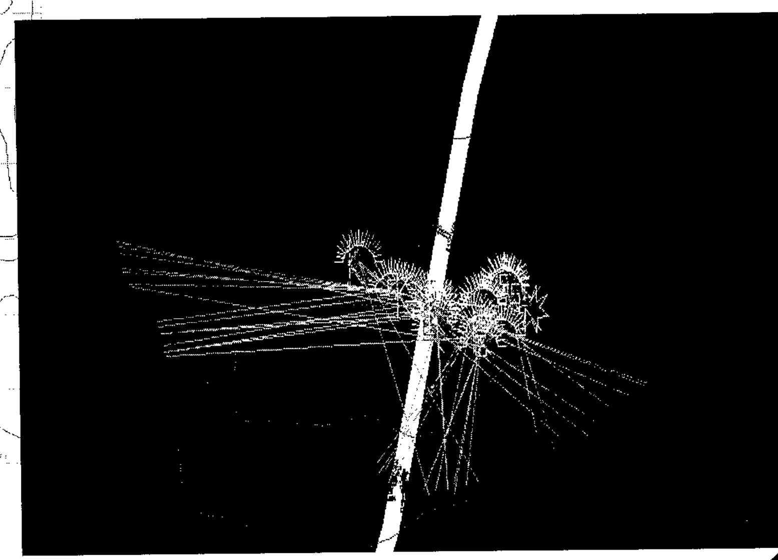
Battlefield Utility



- North Korean mechanized battalion
- 3 rifle platoons



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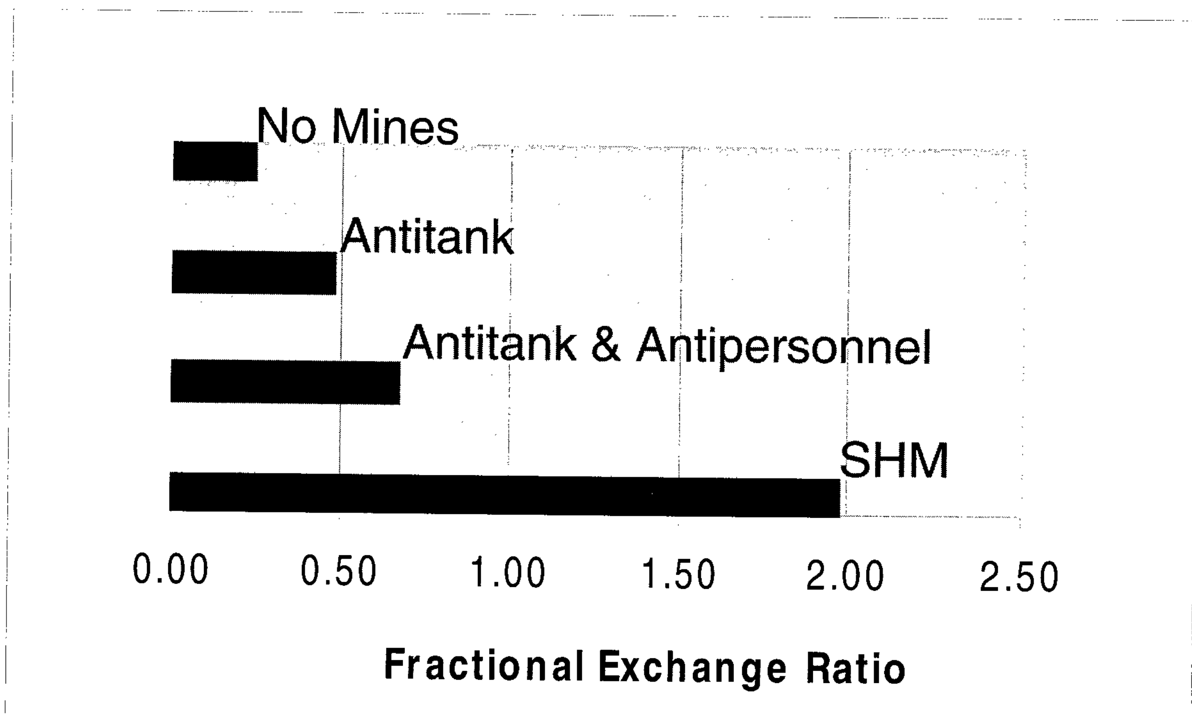
Battlefield Utility

The Self-Healing Minefield significantly increases Blue battle performance



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Development Issues

- Distributed network comm.
  - Low power
  - Jam resistant
- Mine mobility
  - Multi-hop reorganization
- Healing behaviors
  - Provides battlefield capability

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Tags/Minimally Guided Munitions

- Attack enemy dismounted maneuver by:
  - –affixing tags to the individual soldier
  - –employing rapid response, dedicated, guided, indirect fire

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Tags/MGM Concept

- Tags are burr-like transmitters picked up as enemy moves through engagement area
- Munitions are simple course correction, cueing on tag to keep dismounted soldier in kill box

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Study Issues

- Tags
  - Development of millimeter-size transmitters
    - ➢ Relay information to munition launch point and during flight
  - Power
  - Packaging, adhesion, cueing, delivery of tags, etc.

Study Issues

- Minimally Guided Munitions
  - C2 - man-in-loop
  - Low cost/high sensitivity receiver
  - Indirect fire - group dynamics and individual feedback
  - Time-of-flight, flight control, logistics, overall efficiency, etc.

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Program Status

- Electronic Dog's Nose
  - www.darpa.mil/dso/rd/applied/uxo
- Self-Healing Minefield
  - Anticipated Summer 99
- Tags/Minimally Guided Munitions
  - FY99 study phase
  - BAA anticipated fall, 1999

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DARPATech 99

Tactical Mobile Robotics

LTC John Blitch
DARPA/ATO

(703) 696-4464
Jblitch@darpa.mil

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Goal

- Develop portable robotic tools which perform useful tasks that humans *can't*
  - **Negotiate confined spaces / hazards undetected**
  - **Multi-modal sensing: 360x360**
  - **Map complex environments rapidly / completely**
  - **Manipulate complex objects**

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System Concept

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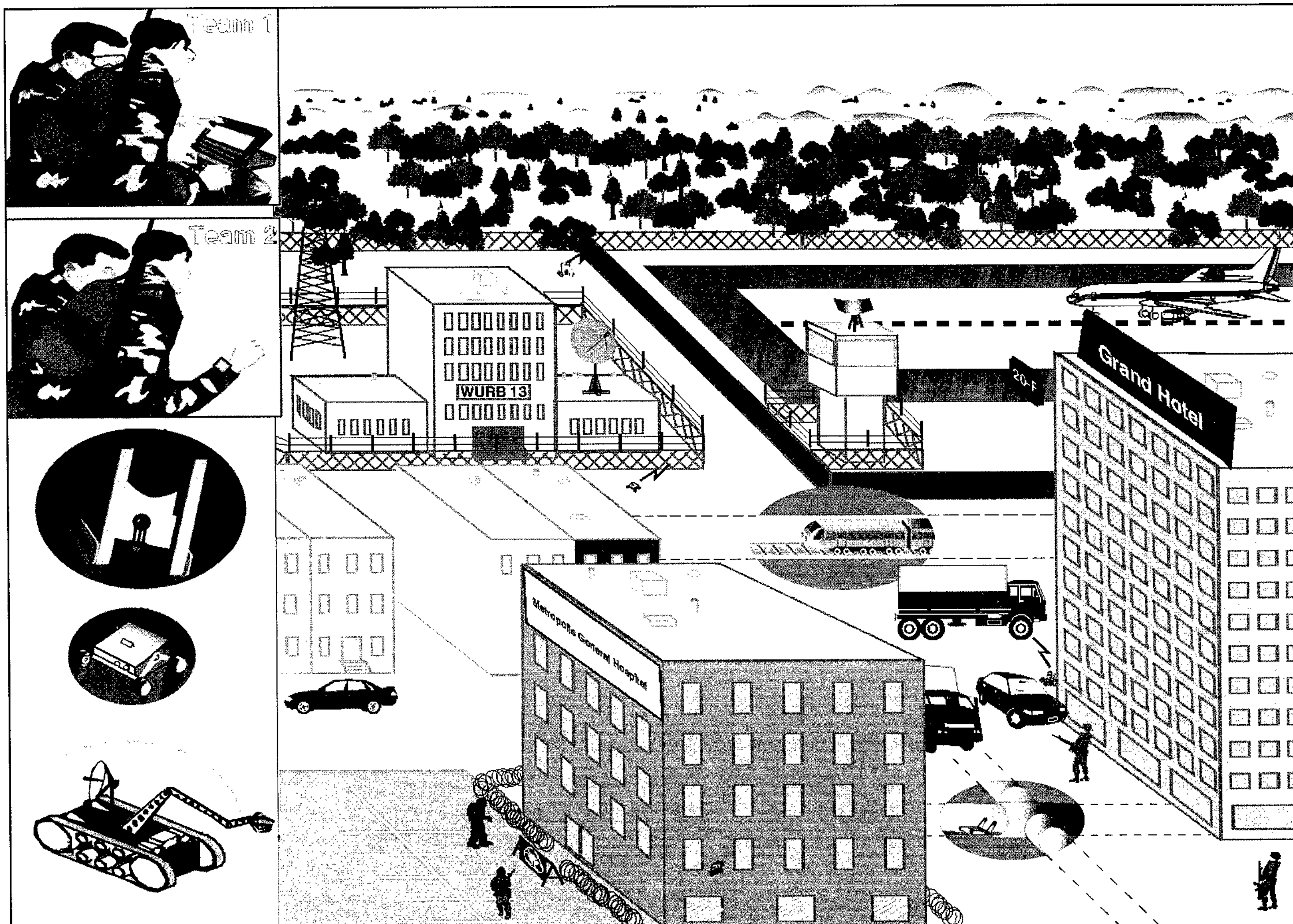

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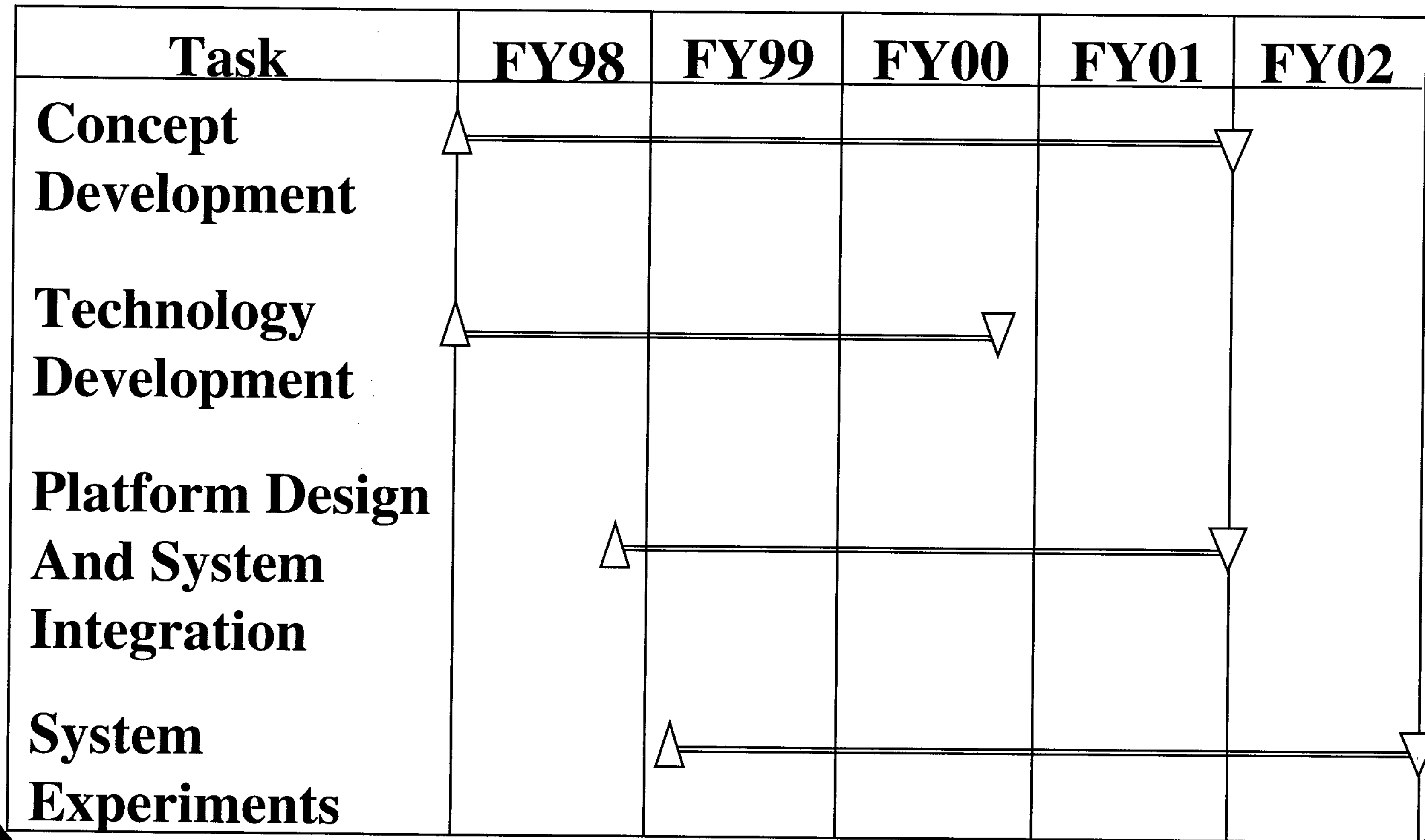
TMR Time Line



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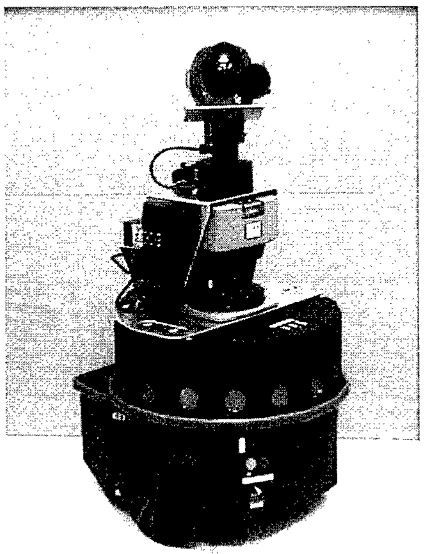
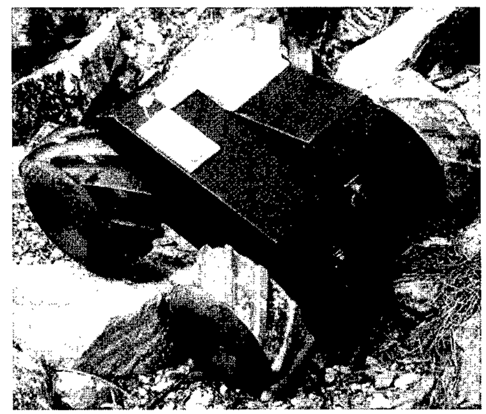
Surrogate Robots For Technology Development

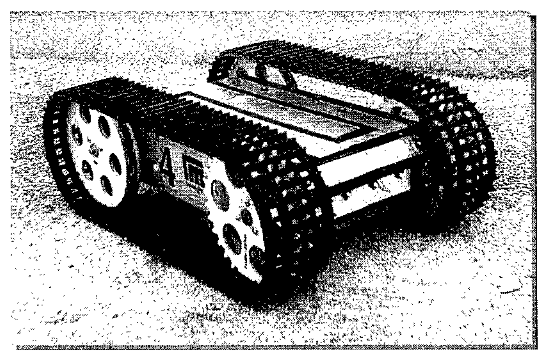


Nomad SuperScout



Sandia Rattler

Foster Miller Lemmings



RWI Pioneer

Technology Goals

Enabling Technology: *Locomotion*

State-of-the-Art	Goal
• Obstacle avoidance	• Barrier negotiation
• Rigid structures	• Variable geometry
• Horizontal translation	• Adaptive climbing

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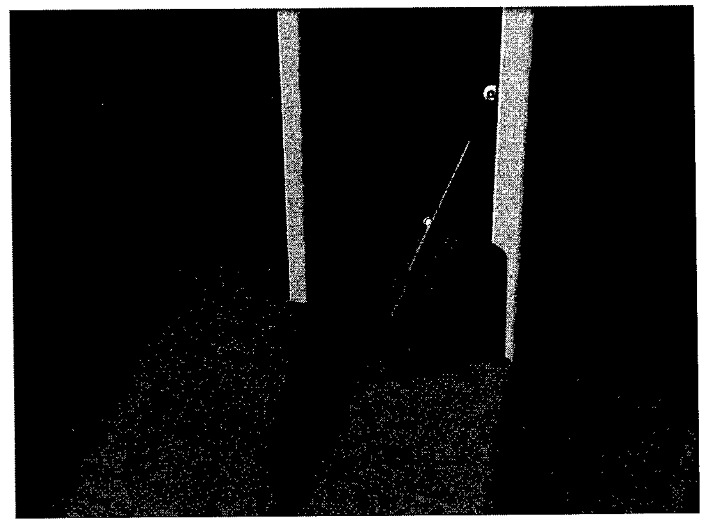
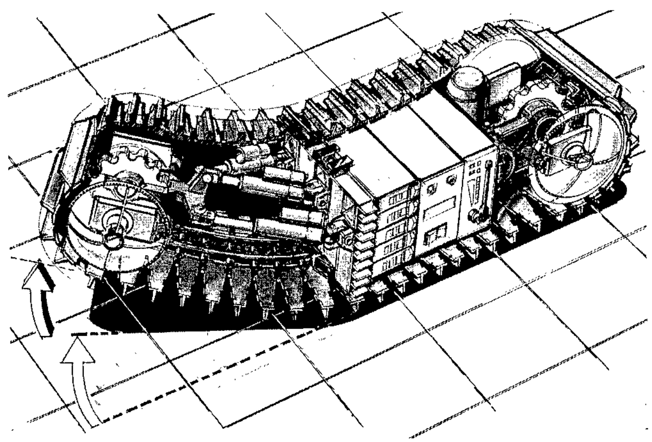
TMR Progress: Locomotion





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Technology Goals

Enabling Technology: *Autonomy*

State-of-the-Art	Goal
• GPS/INS waypoint sequence	• Visual servoing
• Info sharing	• Collaborative mobile manipulation
• Cascading systems	• Marsupial operations

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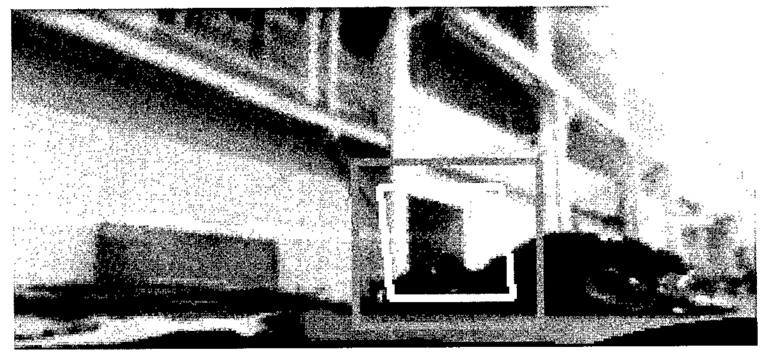
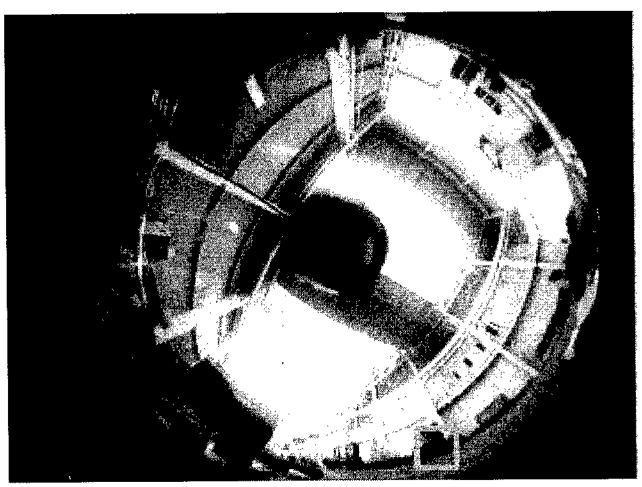
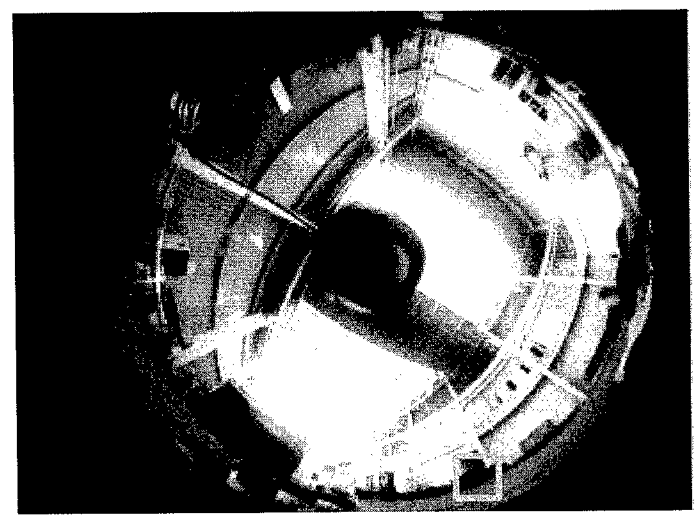
TMR Progress: Autonomy







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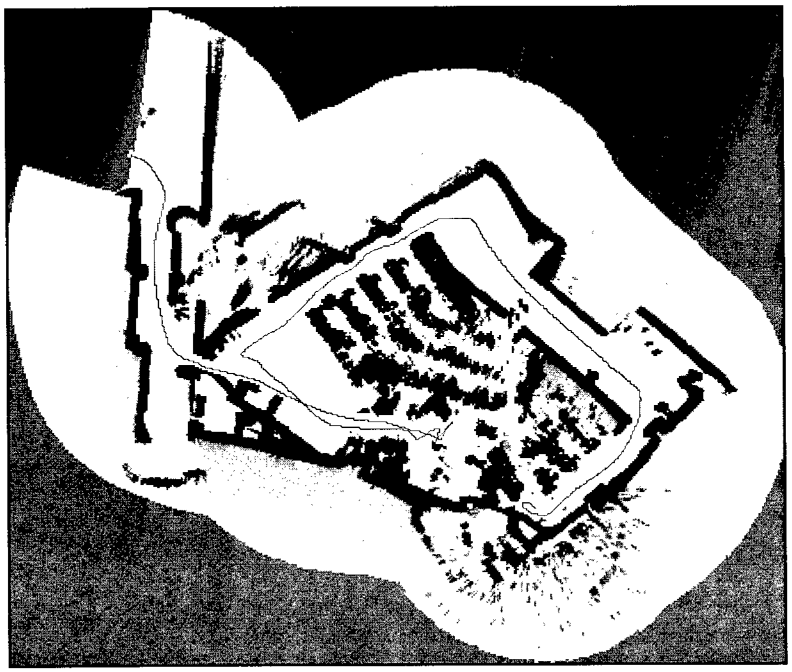
Technology Goals

Enabling Technology: *Machine Perception*

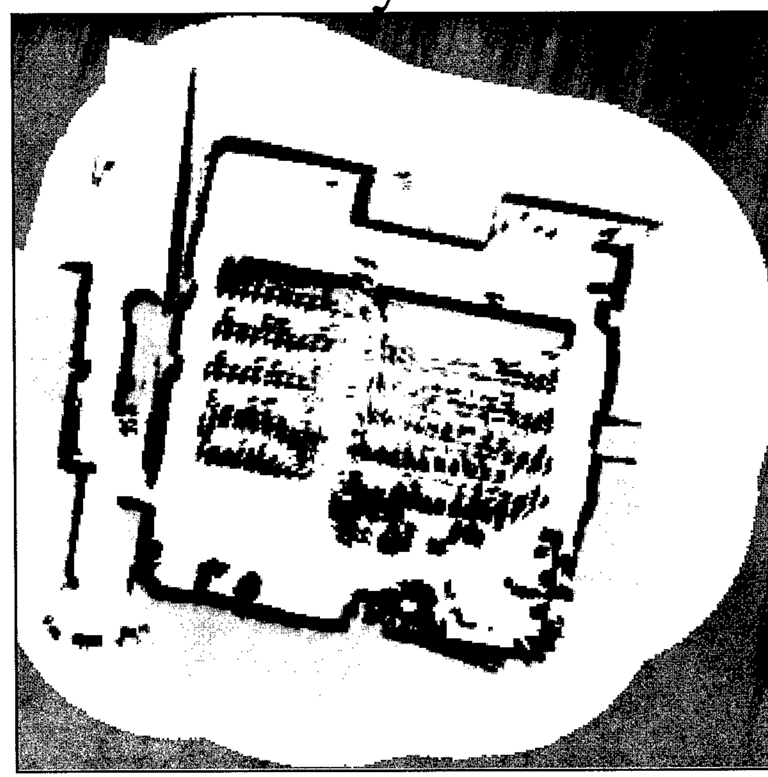
State-of-the-Art	Goal
• Stereo vision (2 Hz)	• Omni vision
• Sonar, radar, range finders	• Penetrating radar, laser scanners
• Single band imagery	• Multi-band fusion
• Edge detection	• Boundary representation
• Planar image transfer	• Distributed Mapping (3-D)

DARPA ATO

TMR Progress: Perception



odometry correction



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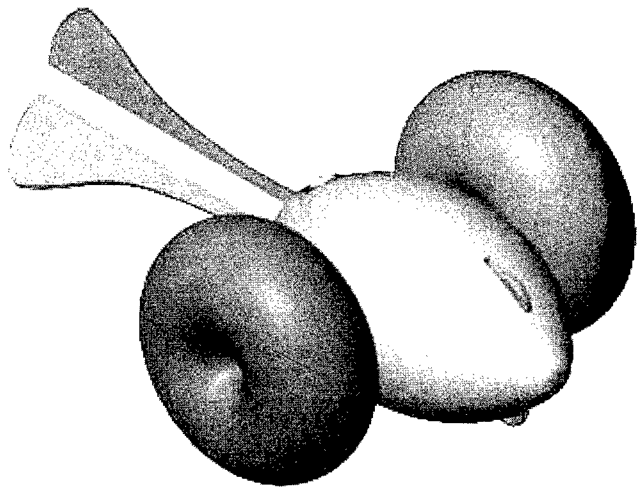
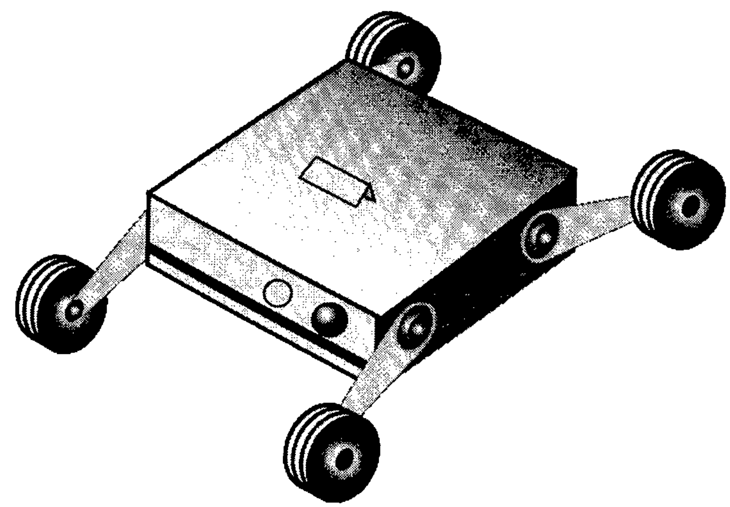
ATO

Throw-bot

(Initial Concepts)





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Systems Integration

- HRI - Human Robot Interface
  - Alert based semi-autonomy
  - Non-distracting gloves, glasses & wearable computer
- CRP - Collaborative Robot Platforms
  - Heterogeneous teaming
  - Marsupial operations

Future Opportunity

- Innovative Mobility BAA
  - wall climbing, compliant surfaces
  - shape shifting, undulation, hybrids
- Collaboration with OSD Joint Robotics Program

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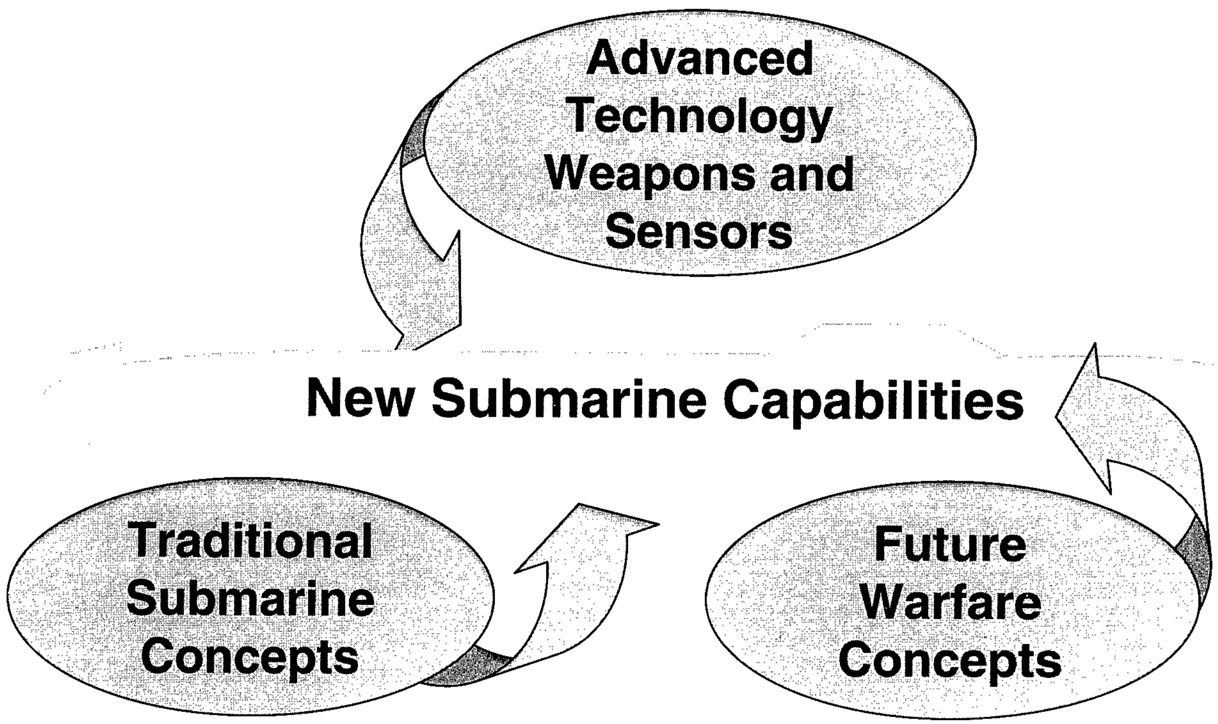
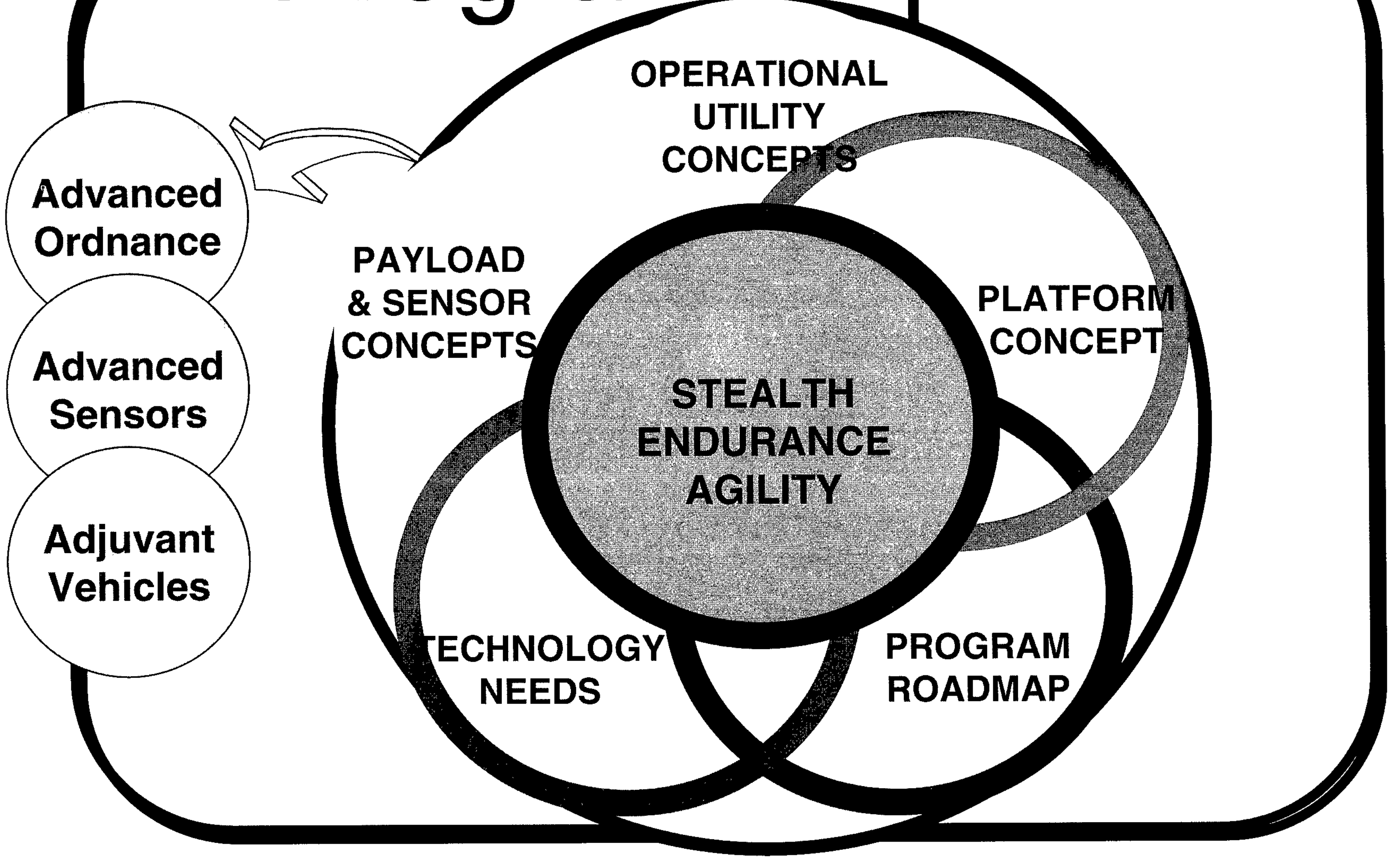
Submarine Payloads and Sensors Program

CAPT John Polcari
Program Manager

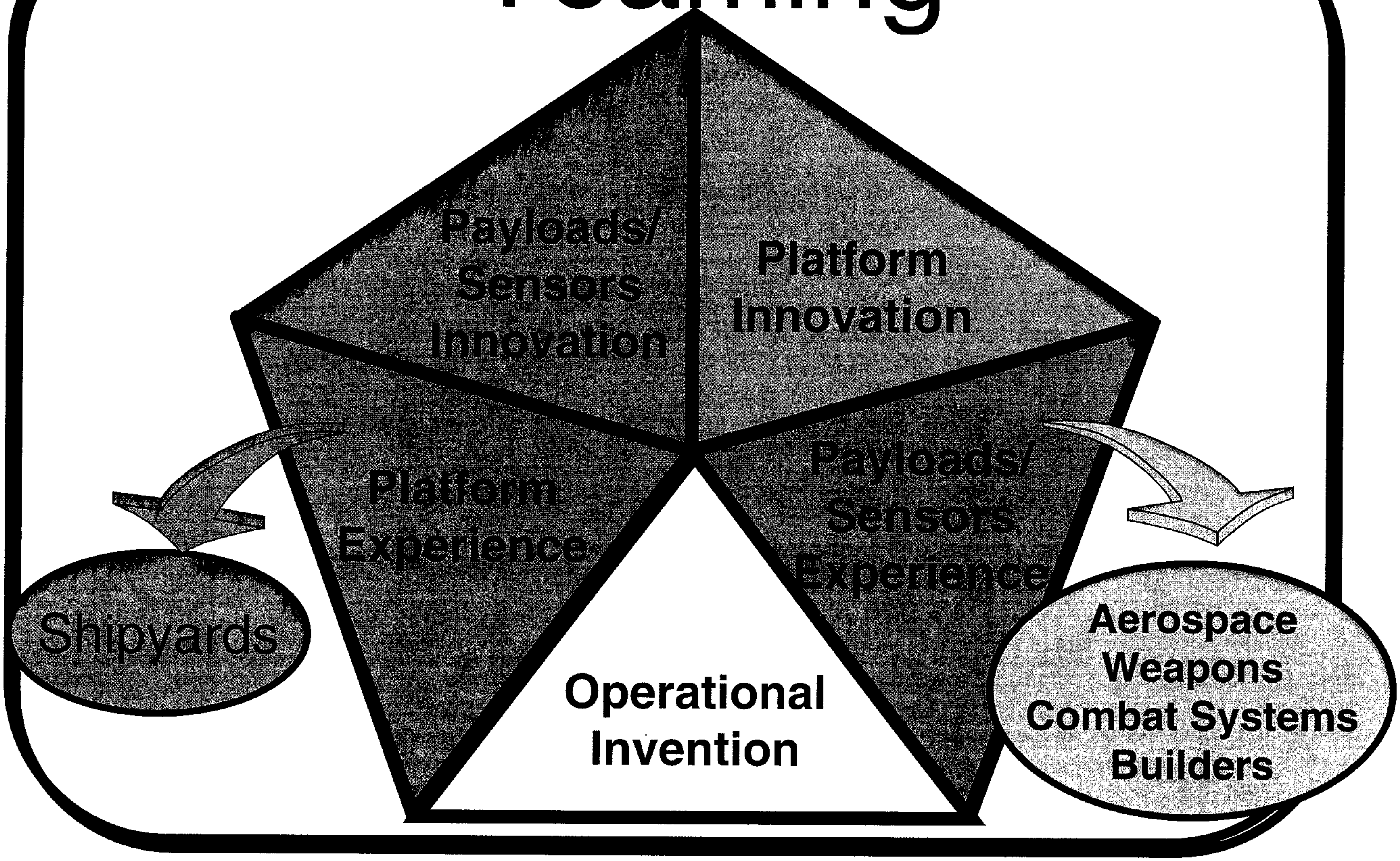
Converging Thrusts



Program Aspects



Teaming


Payloads/
Sensors
Innovation
Platform
Innovation
Platform
Experience
Payloads/
Sensors
Experience
Operational
Invention
Shipyards
Aerospace
Weapons
Combat Systems
Builders

Program Structure

[redacted]

Initial Concept

Phase 0
"Develop the Game Plan"
18 months
2 Teams

Bridge ROM

PR01 Budget

Priming the pump

Final Concepts

Final Deliverables

FY01 Bridge
"Follow-on Studies"
12 months
?? Teams

Interim Deliverables

POM02 Budget

The Future ?
- Technology maturation ?
- Risk reduction ?
- Demonstrations ?
- Eng. development ?
- Backfit / forward fit ?
- Class variant ?

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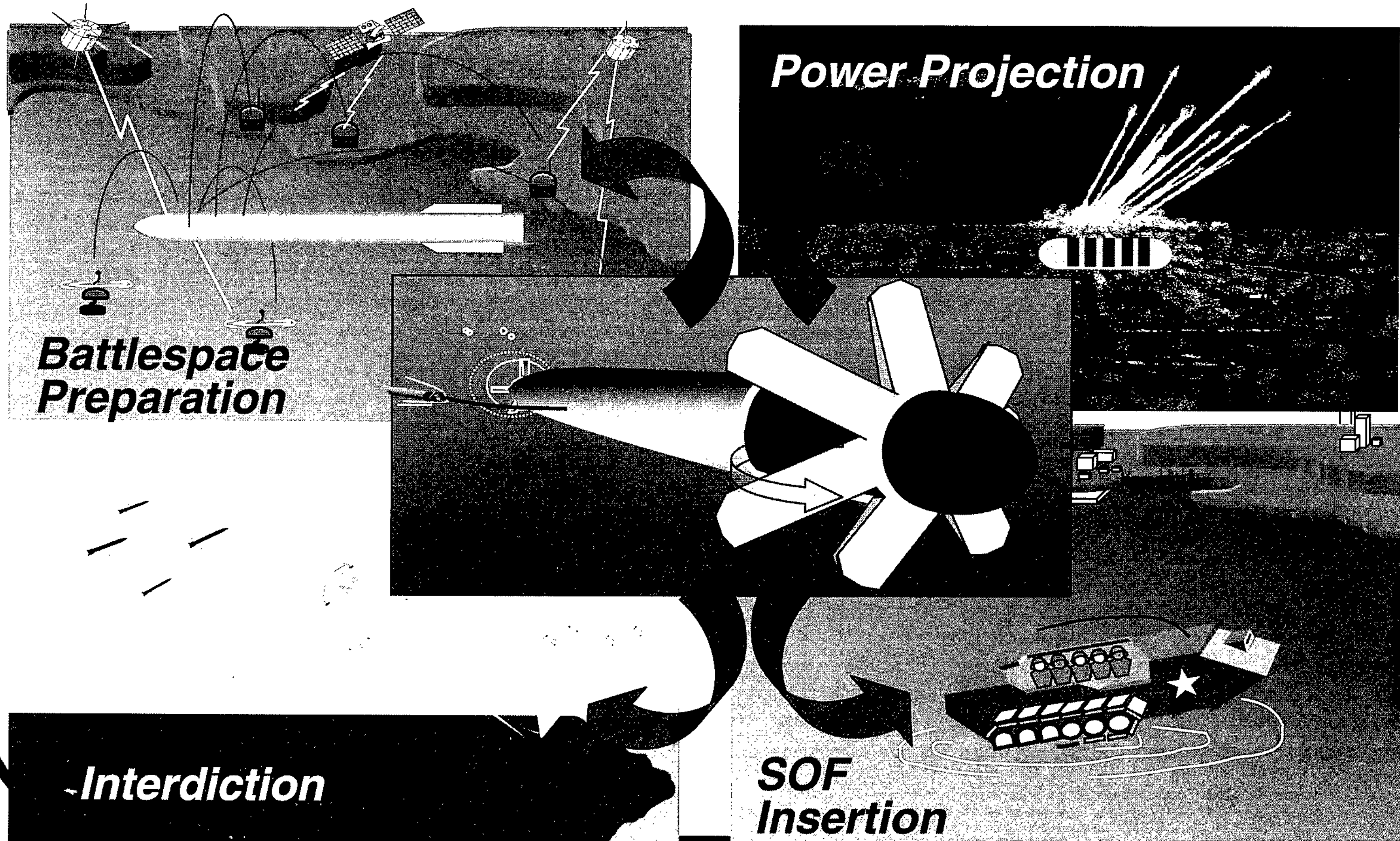
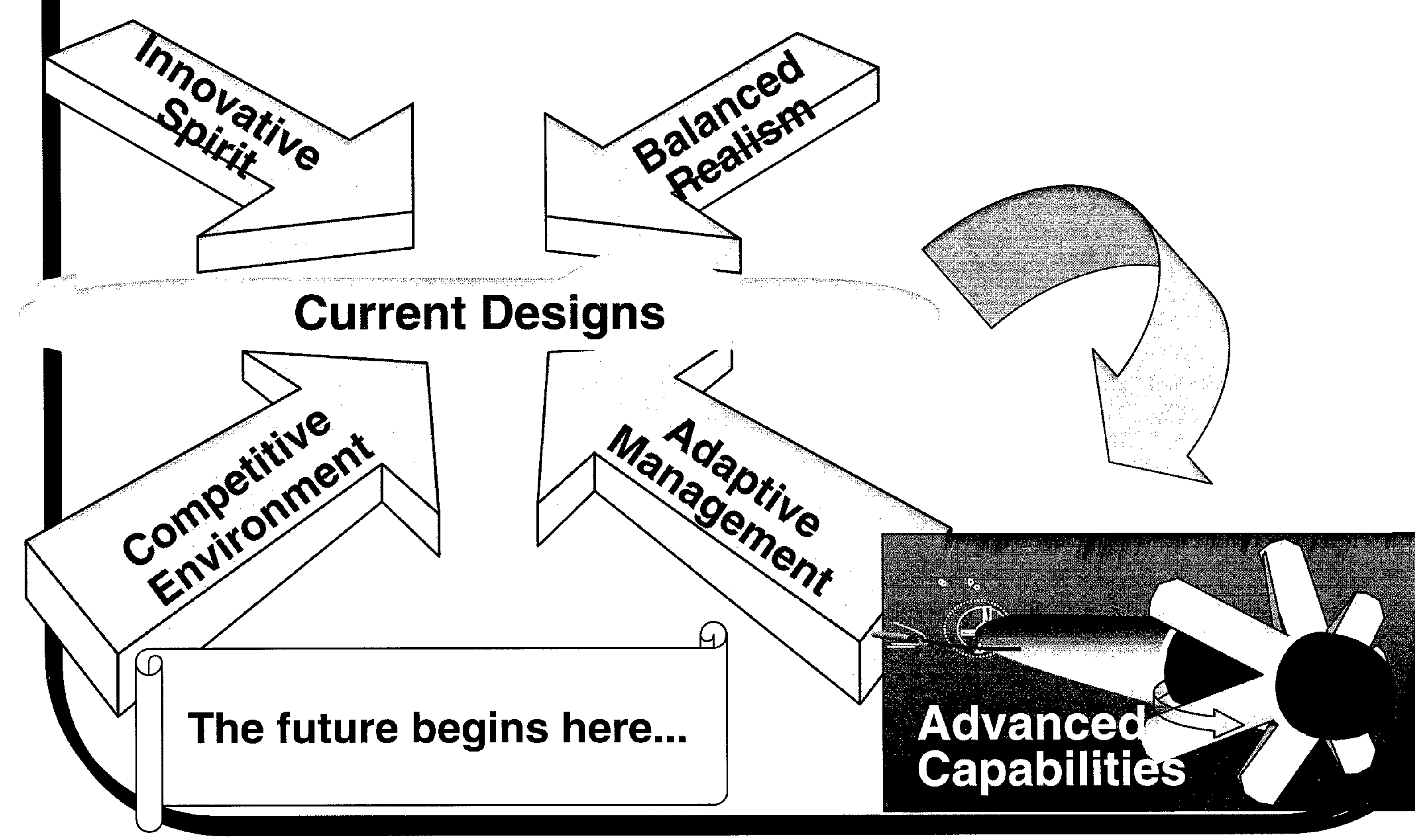
New Concepts



Program Goal



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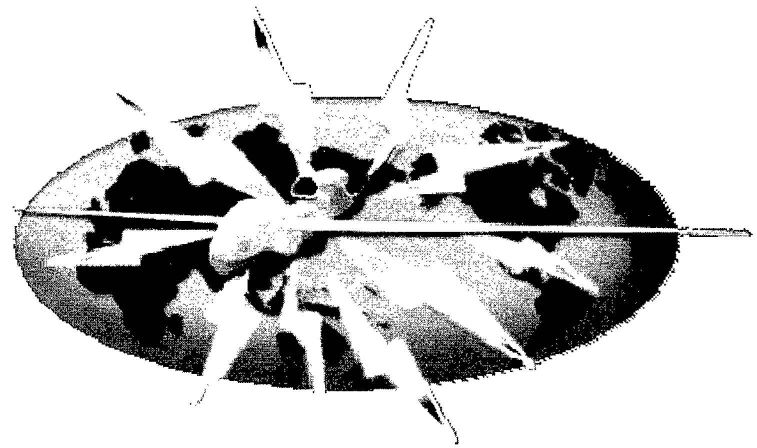
ATO



Airborne Communications Node (ACN)

Ms. Gladys Reichlen

DARPA ATO

ACN Goals

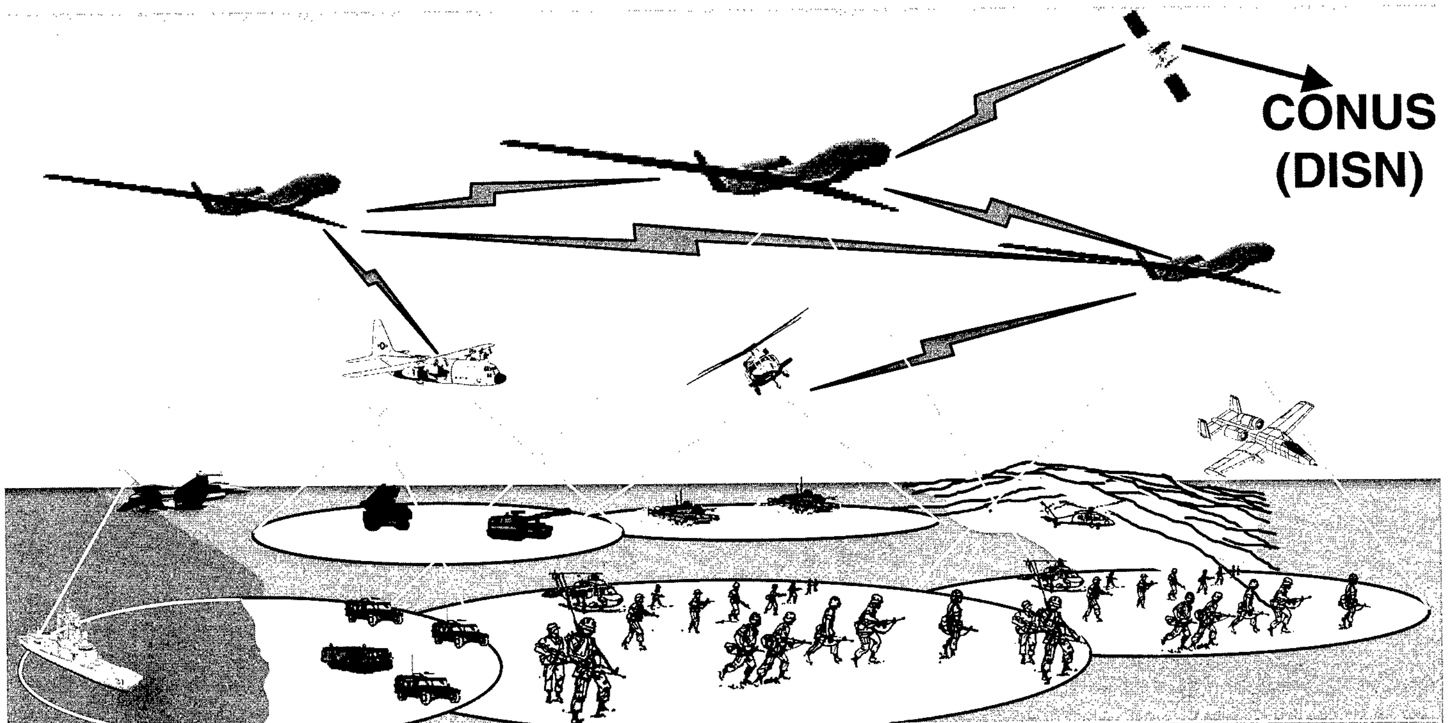
Multi-Function Comm Node Supporting On-the-Move Forces with Enhanced:

- **Connectivity**
- **Coverage**
- **Throughput**
- **Interoperability**

ACN061v001

DARPA ATO

ACN Connectivity



Augments/Enhances Existing Infrastructure

ACN Features

- Autonomous Wireless Infrastructure
- Dynamic Payload Control and Configuration
- Adaptable to Any Mission

ACN044v001

ACN Payload

A Highly Flexible, Generic Communications System that's:

- Reprogrammable at the Waveform Level
- Reconfigurable at the Channel Level
- Modularly Constructed
- Scaleable to Any Platform

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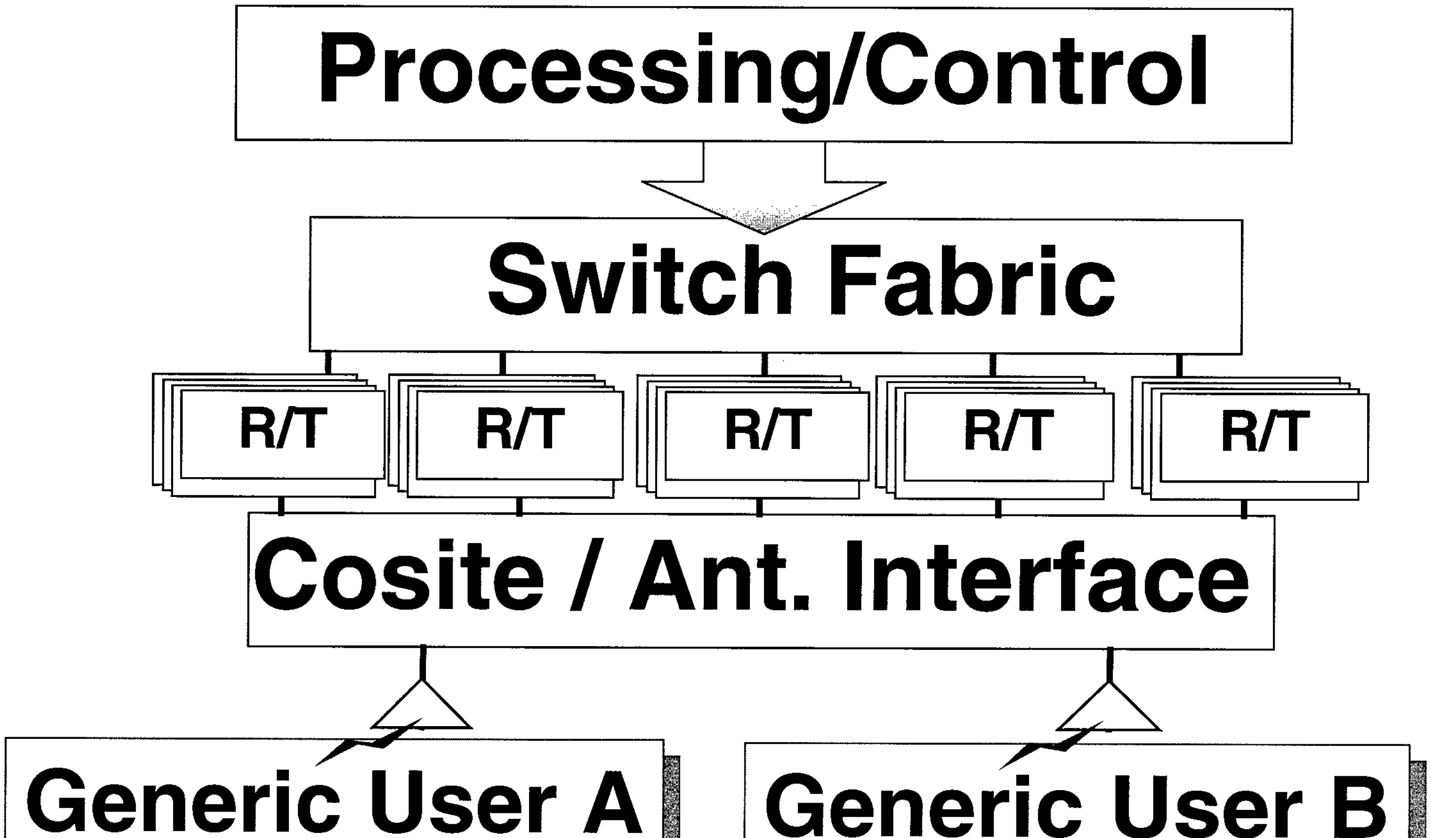
ATO

ACN Design



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ACN Services

Functionality	*Level*
Range Extension	
• SINGARS	10 - 20 User Pairs
• UHF LOS/Have Quick	10 - 20 User Pairs
• EPLRS	1 - 3 Channels
• Link 16	1 Channel
• TWR (MSE)	2 - 4 Channels

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ACN Services

Functionality	Level
• Dissimilar Radio Interoperability	Any to Any
• UHF Surrogate Satellite	10 - 20 User Pairs
• High Speed Infrastructure Access	10 - 45 Mbps
• Tactical Battlefield Multicast	64 - 1,544 Kbps
• Internet-like Data Networking	400 - 600 Users
• Alpha-Numeric Paging	500K Addresses
• Cellular / PCS-Like Voice / Data	50 - 200 Calls

DARPA ATO

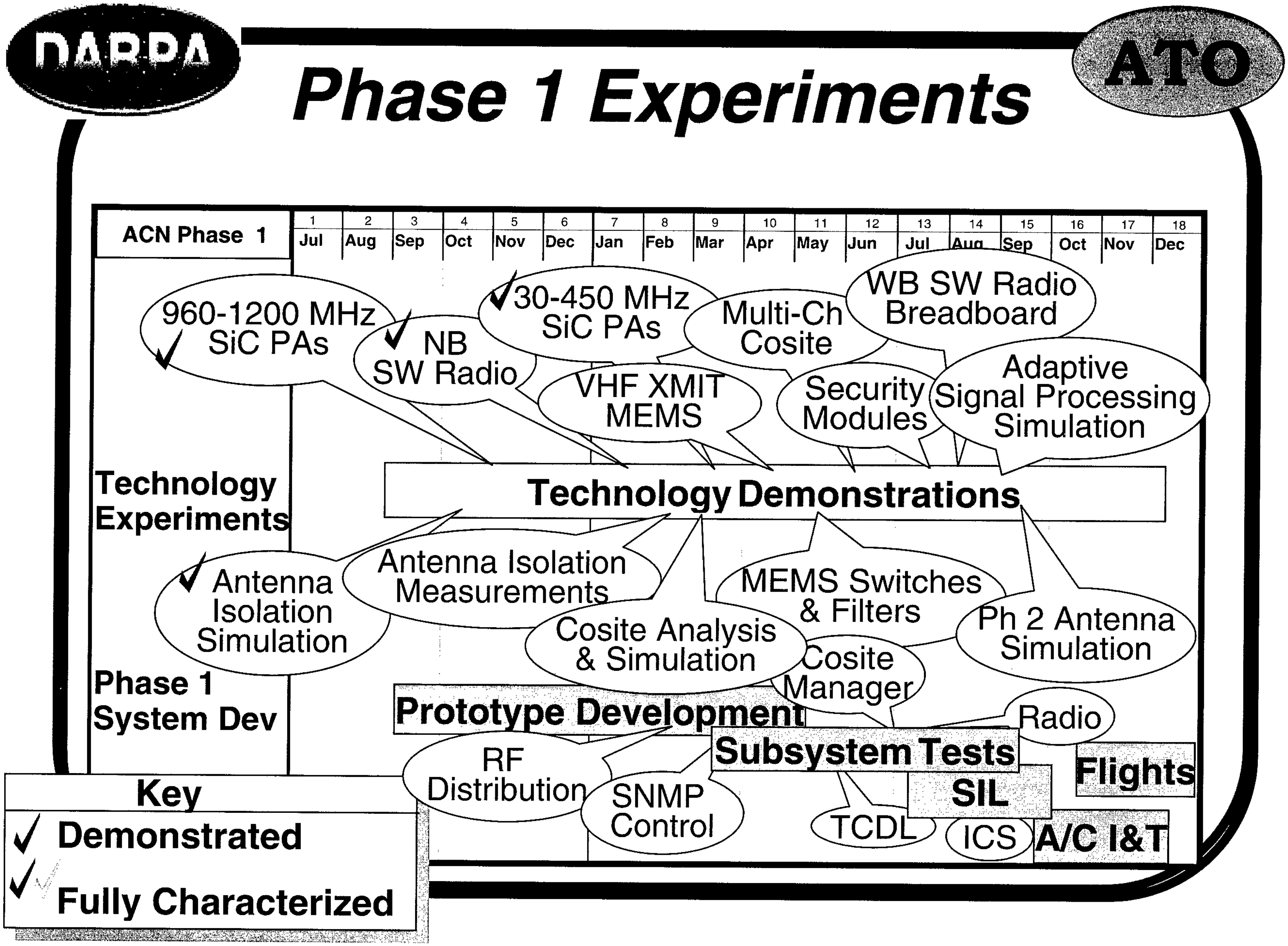
Performance Objectives

SWAP

- **Volume** 100 - 130 cu ft
- **Weight** 450 - 900 lbs
- **Power** 5 - 9.7 kW

Range 100 - 150 mi

Phase 1 Experiments



ACN065v001

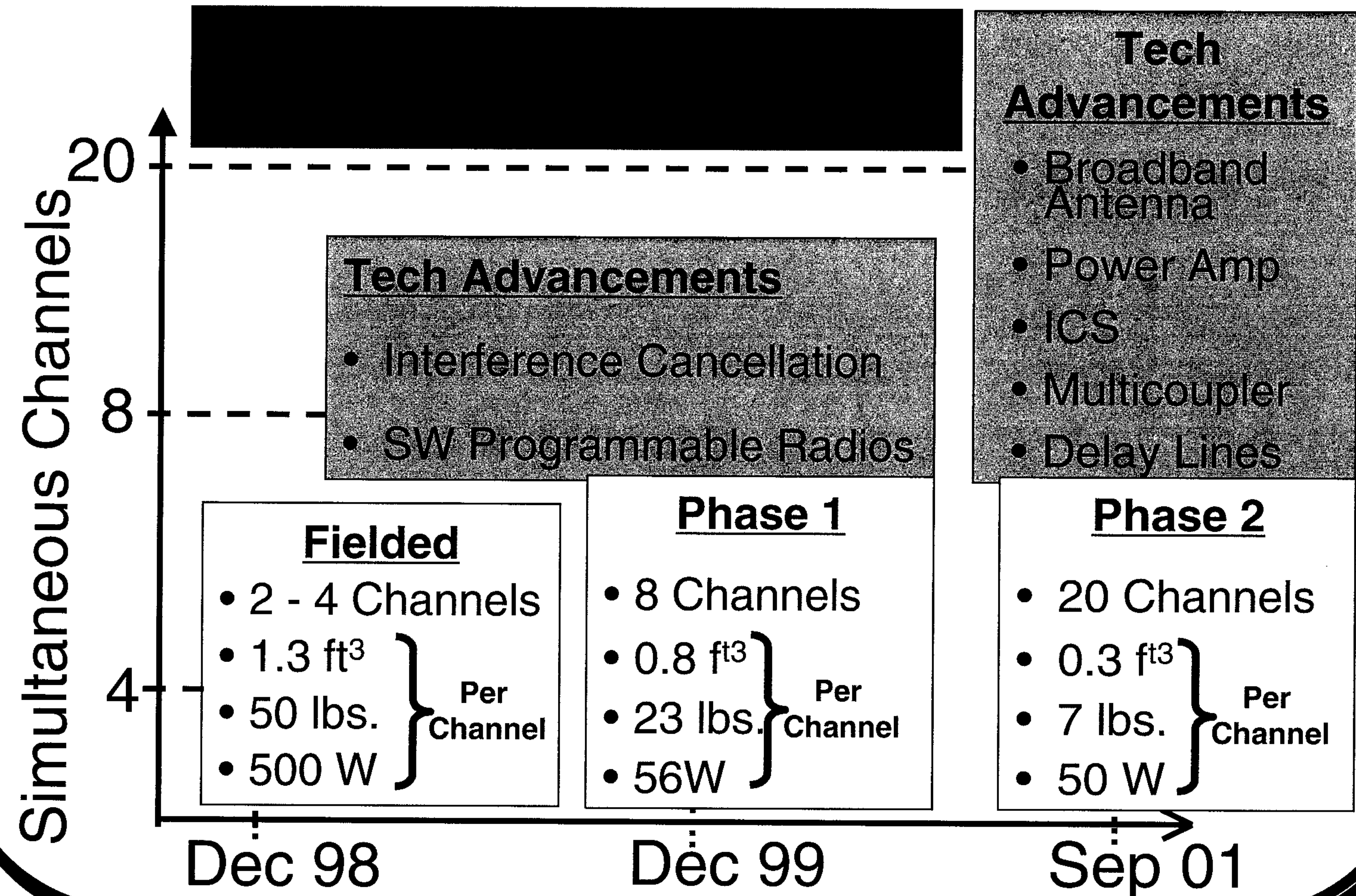
DARPA ATO

ACN Key Challenges

- Complex Interference Environment
  - Cosite Interference
  - Electromagnetic Compatibility
  - Intentional / Unintentional Jamming
- Size, Weight, & Power (SWAP)

DARPA ATO

Interference Mitigation



ACN065v001

DARPA

ATO

Other ACN Challenges

- Adaptive Mobile Communications
- Waveform Supportability
- Scalability and Modularity
- Security
- Commercial Services

ACN008v001

DARPA

ATO

Phase 1 Teams

SANDERS
A Lockheed Martin Company

Bellcore
Bell Communications Research

LOCKHEED MARTIN
Tactical Defense Systems, Eagan, MN

L3 communications

MOTOROLA

SAIC Science Applications International Corporation
An Employee-Owned Company

SRC Scientific Research Corporation

ViaSat

XETRON

Raytheon

Ball

GEC-

GTE

HARRIS COMMUNICATIONS

Houston

HRL LABORATORIES

QUALCOMM

ZA

BOEING

GDE Systems Inc
a Tracor company

GTE
INTERNETWORKING
POWERED BY BBN

L3 communications

Rockwell Collins

UCSD

Low Cost Cruise Missile Defense (LCCMD) Program

Lt Col Ed Gjermundsen
DARPA/SPO

DARPA

SPO

OUTLINE

- MOTIVATION
- THREAT
- PROGRAM DESCRIPTION
- TECHNICAL APPROACHES
- SUMMARY

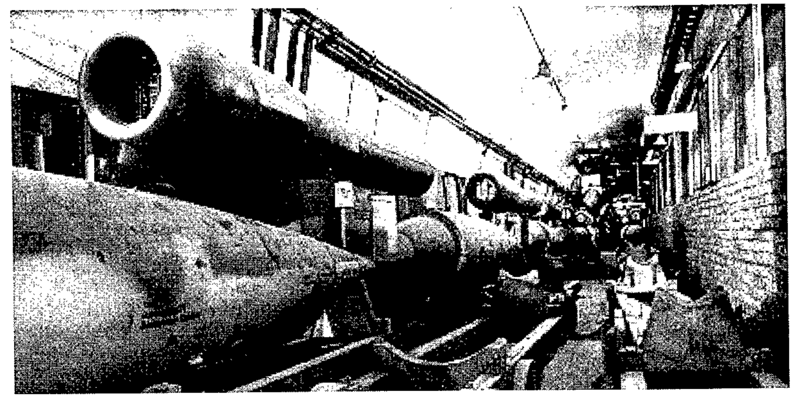
DARPA

SPO

MOTIVATION

THEN…
- 30,000 Produced
- $3K/unit

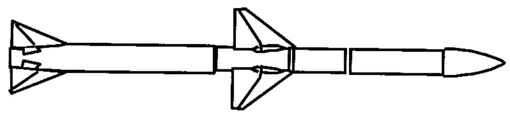
NOW…
- 70,000 Worldwide
- $150K-$1M/unit



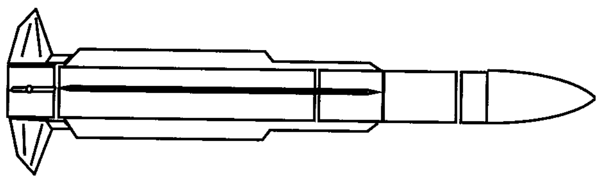
GERMAN V-1

MODERN CRUISE MISSILE

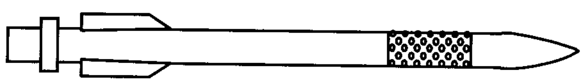
US Air Defense



AMRAAM



Standard Missile

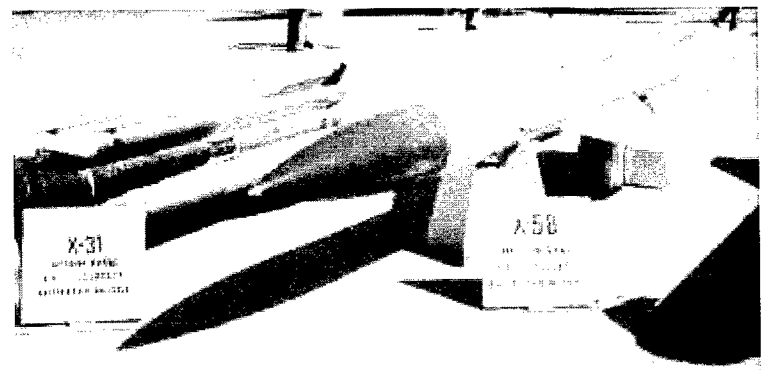


Patriot

- **Cruise Missile Defense**
- **Ballistic Missile Defense**
- **Anti-Air Warfare**

Cruise Missile Threat

- 82 Countries Possess
- 75 Systems in Service
- 42 in Development



Russian AS-11/KH-58

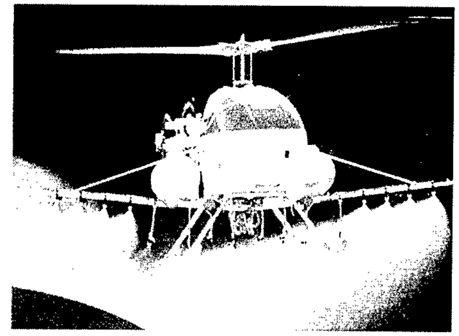
French Armat

DARPA

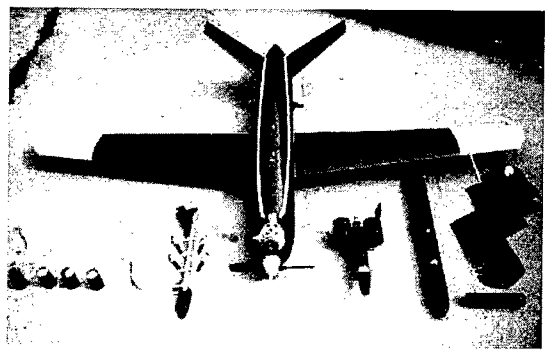
UAV Threat

SPO

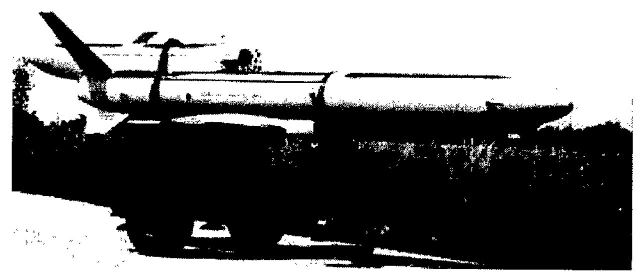
- 74 Systems in Service
- 51 in Development



CHEM/BIO WARFARE

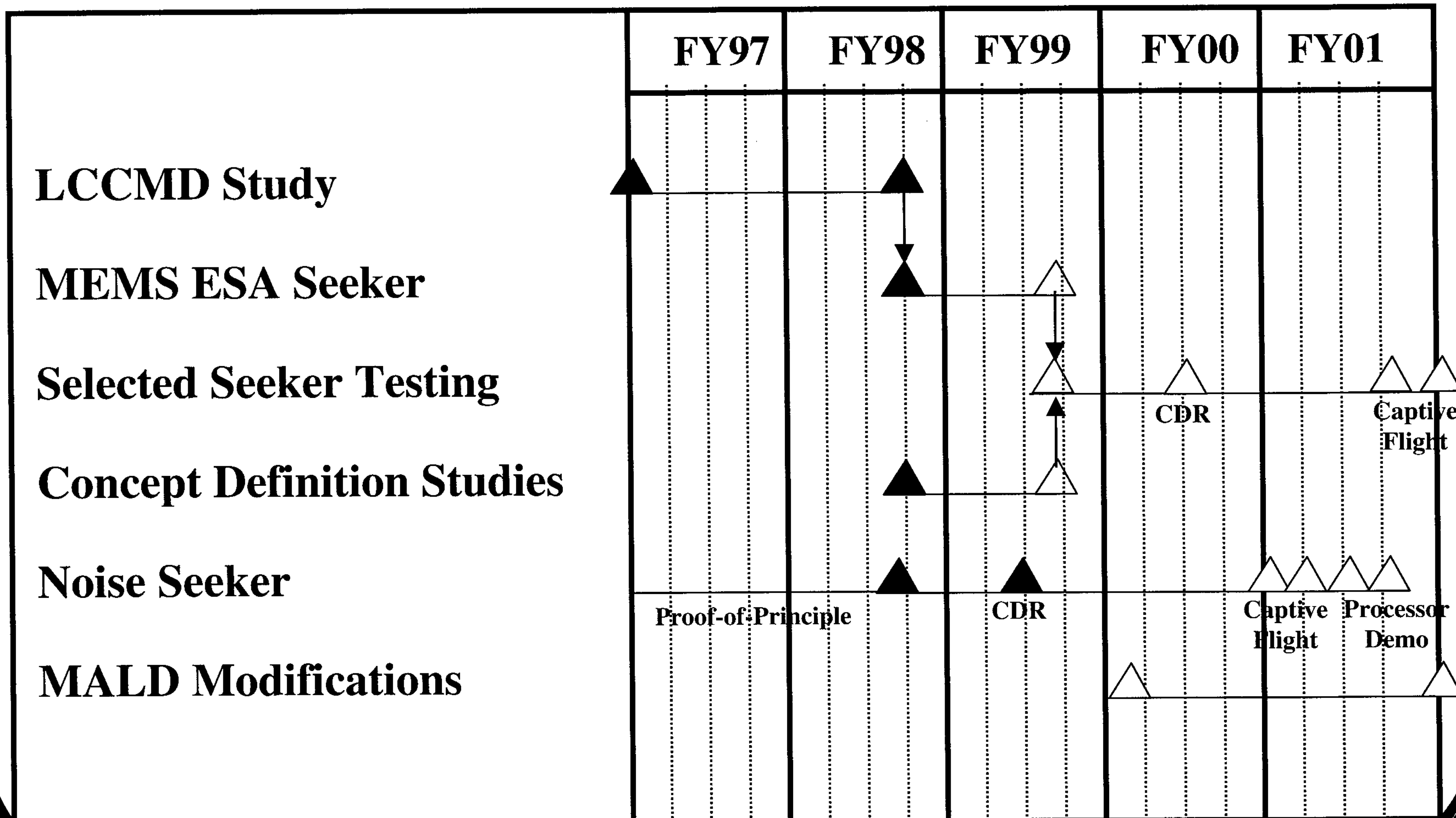


INFO DOMINANCE



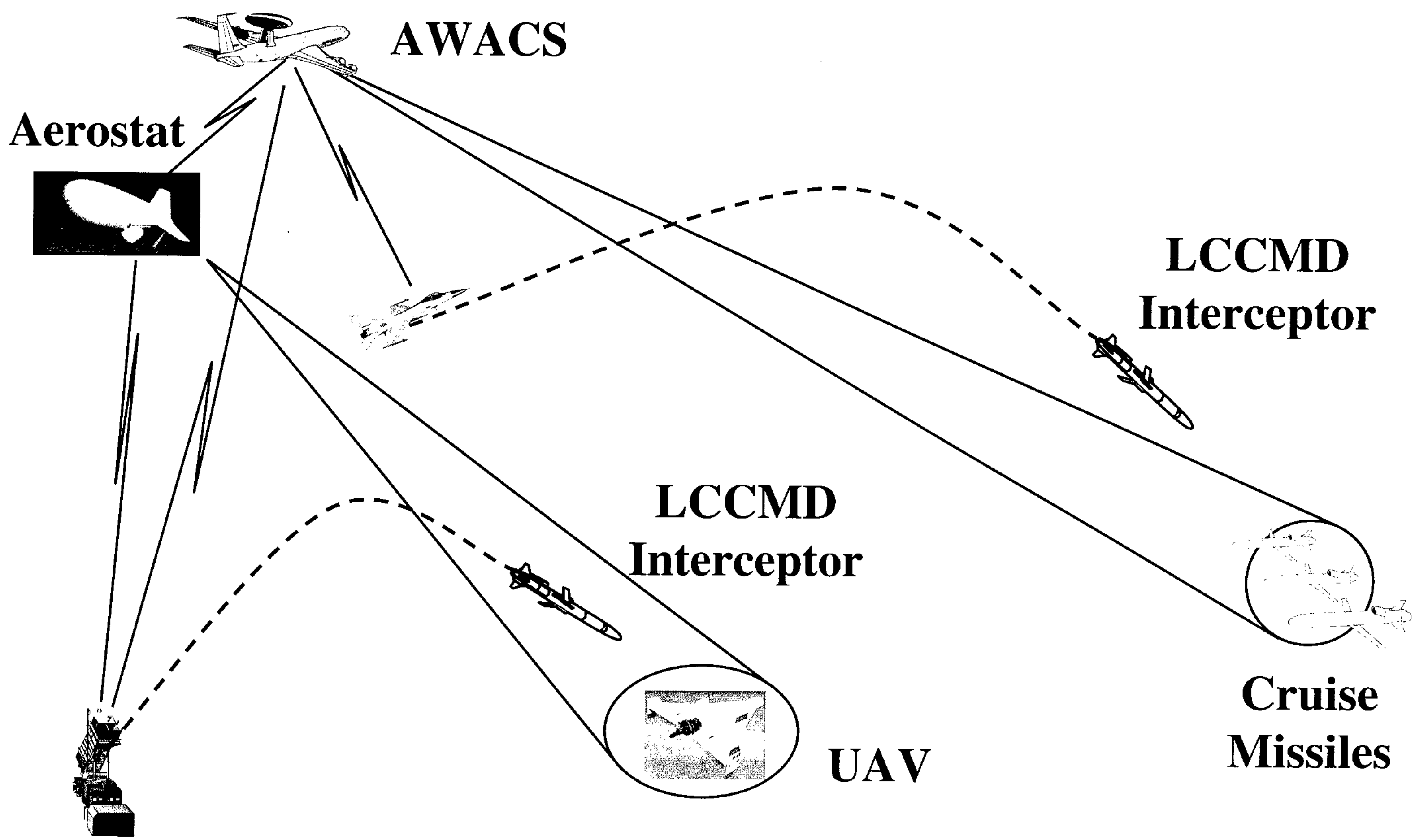
CONVENTIONAL WEAPONS

Schedule

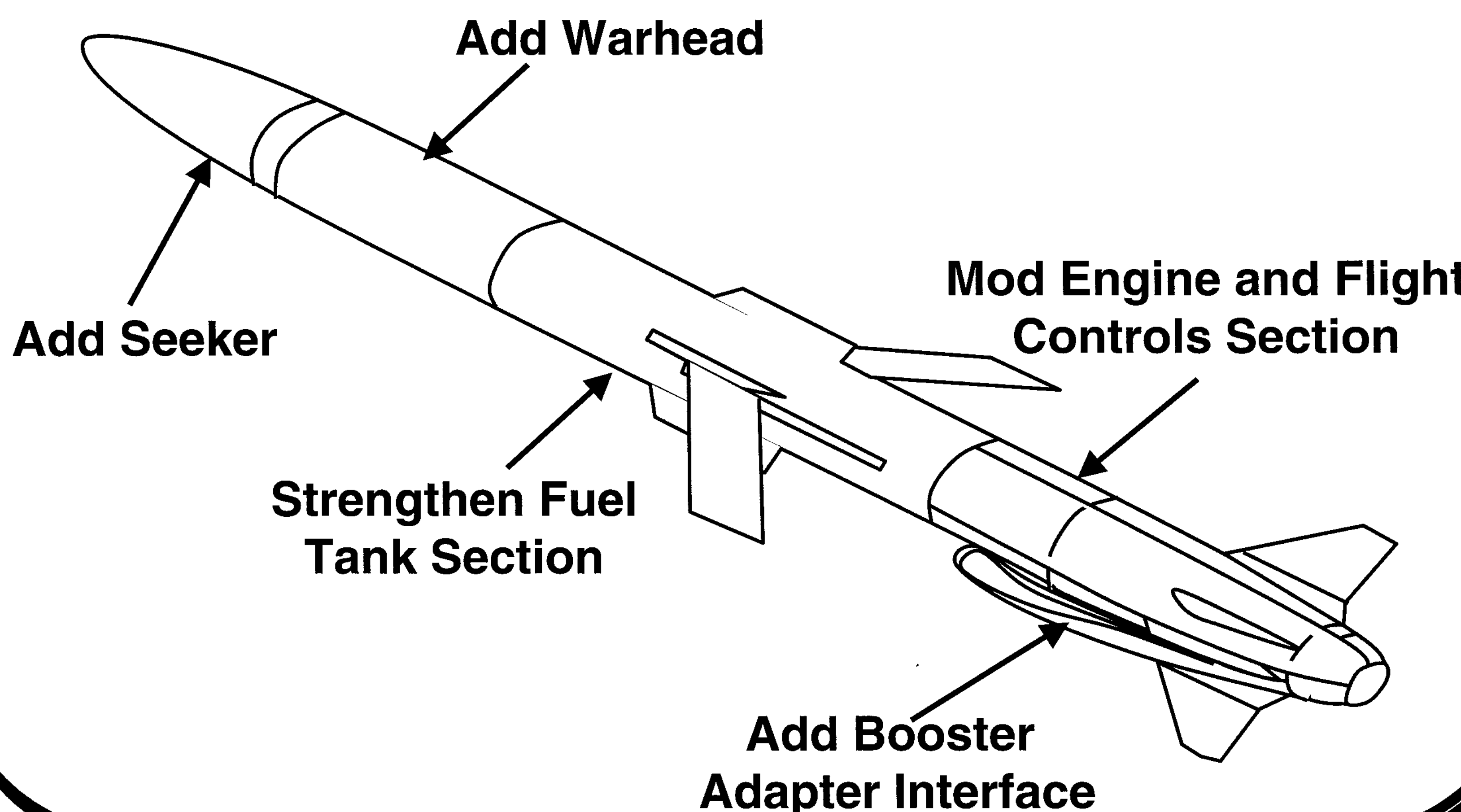


DARPA
SPO
FY97
FY98
FY99
FY00
FY01
LCCMD Study
MEMS ESA Seeker
Selected Seeker Testing
Concept Definition Studies
Noise Seeker
MALD Modifications
CDR
Captive Flight
Proof-of-Principle
CDR
Captive Flight
Processor Demo

LCCMD CONOPS

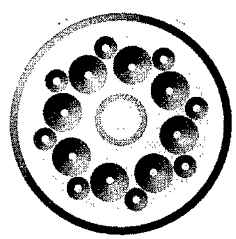


MALD-Interceptor

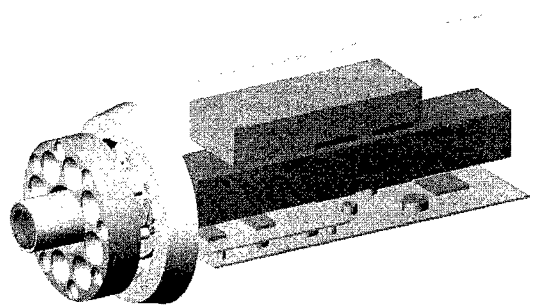


Seeker Approaches

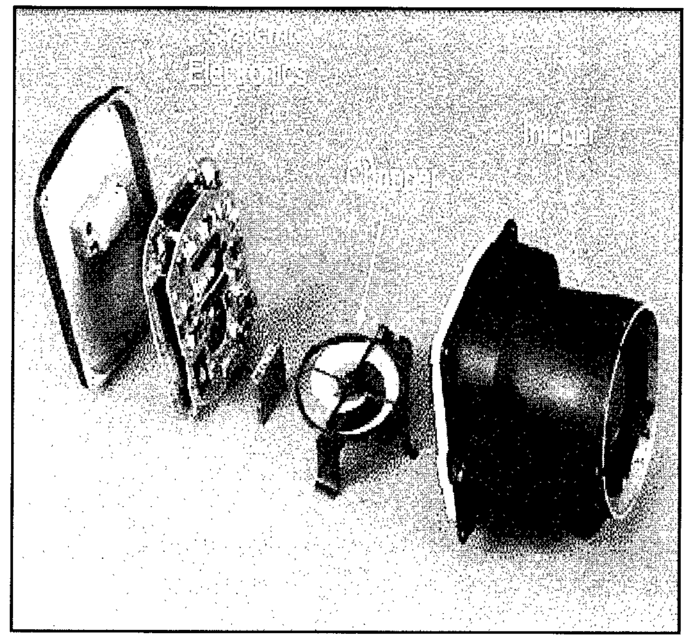
Front View



Side View

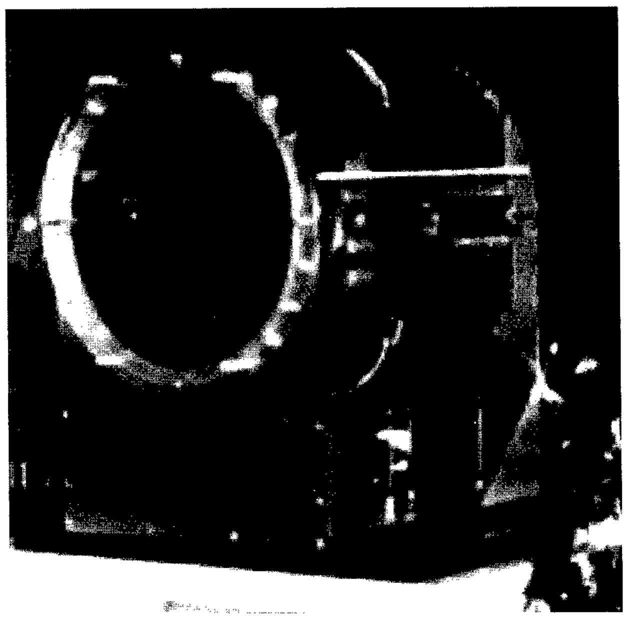


Ladar Seeker



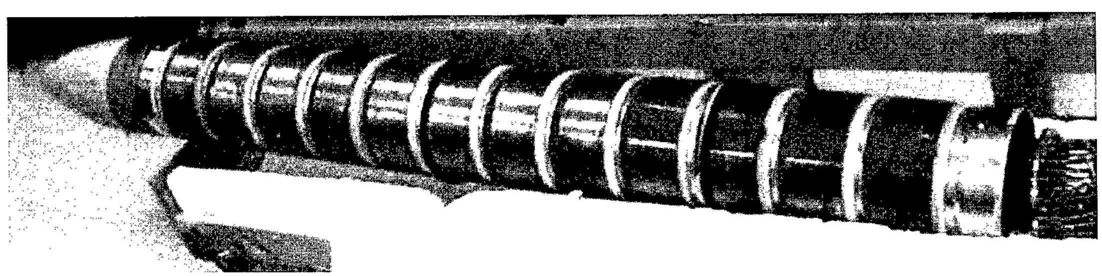
Infrared Seeker

Antenna Technologies

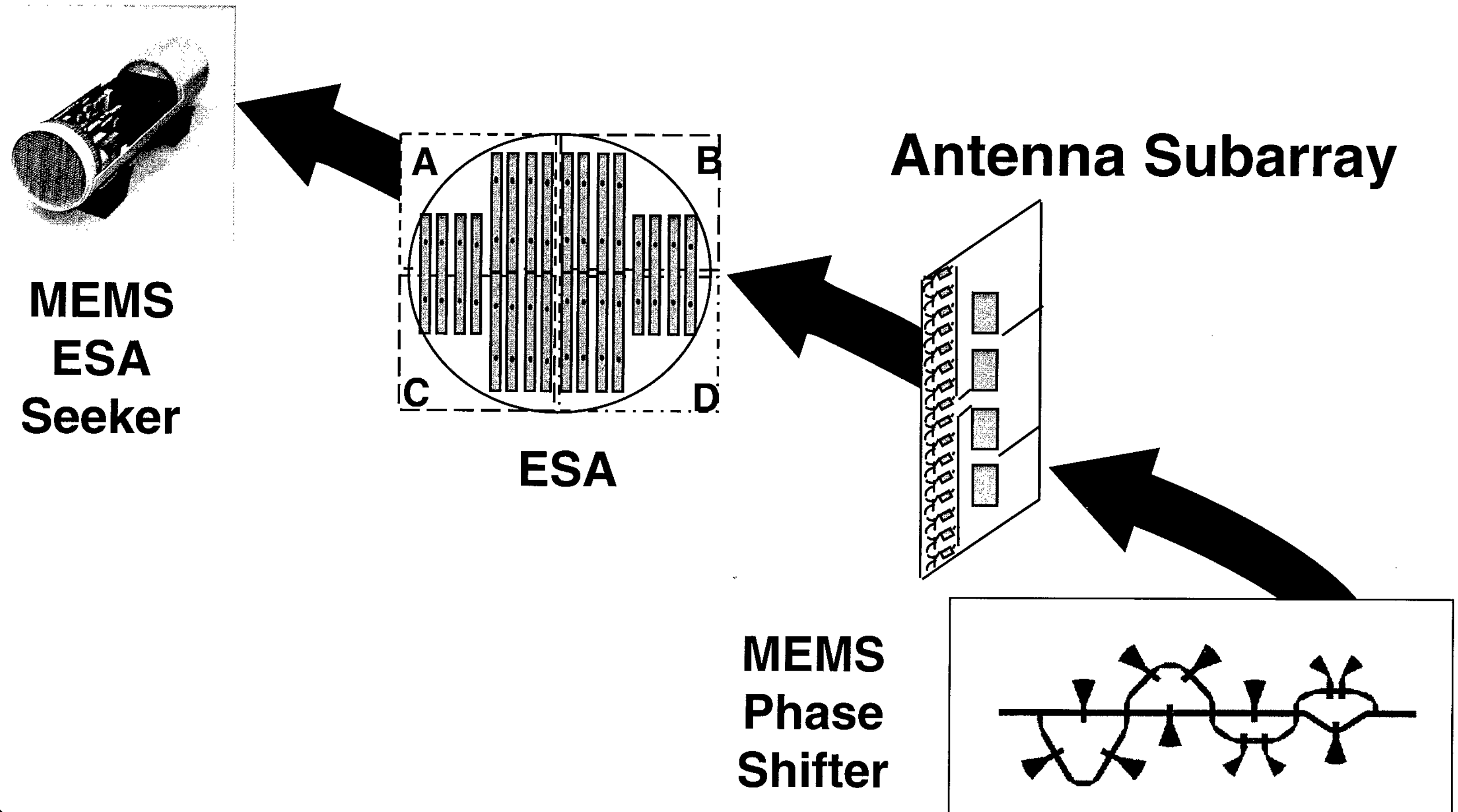


Optically Steerable Antenna

UHF Antenna



MEMS ESA Seeker



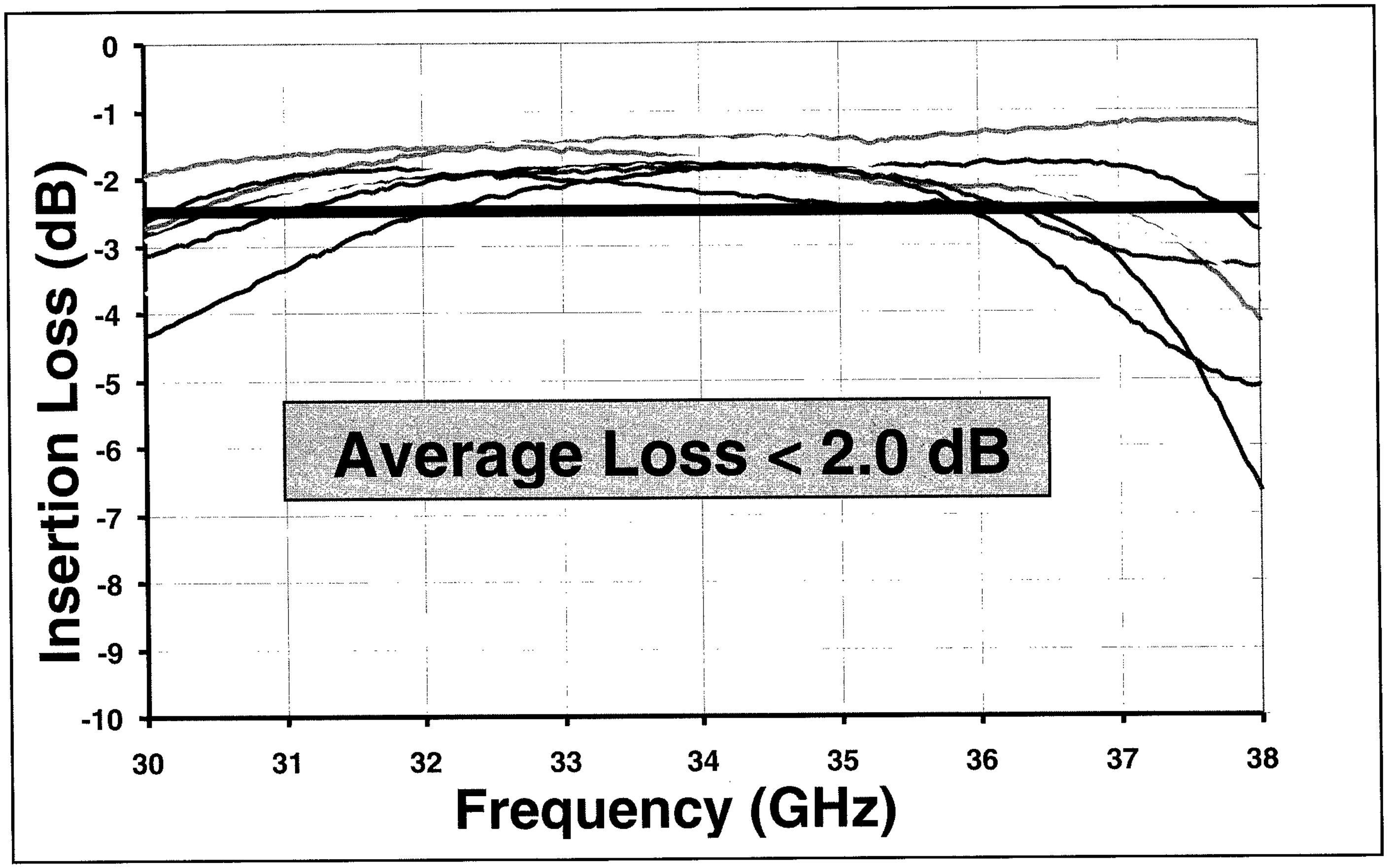
MEMS
ESA
Seeker

ESA

Antenna Subarray

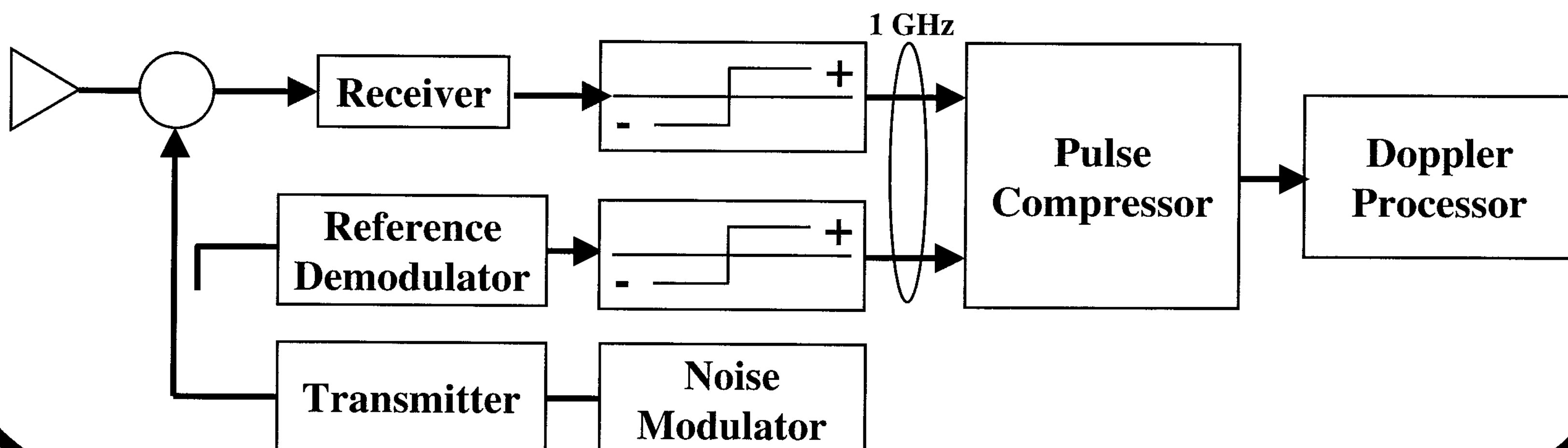
MEMS
Phase
Shifter

Phase Shifter Losses

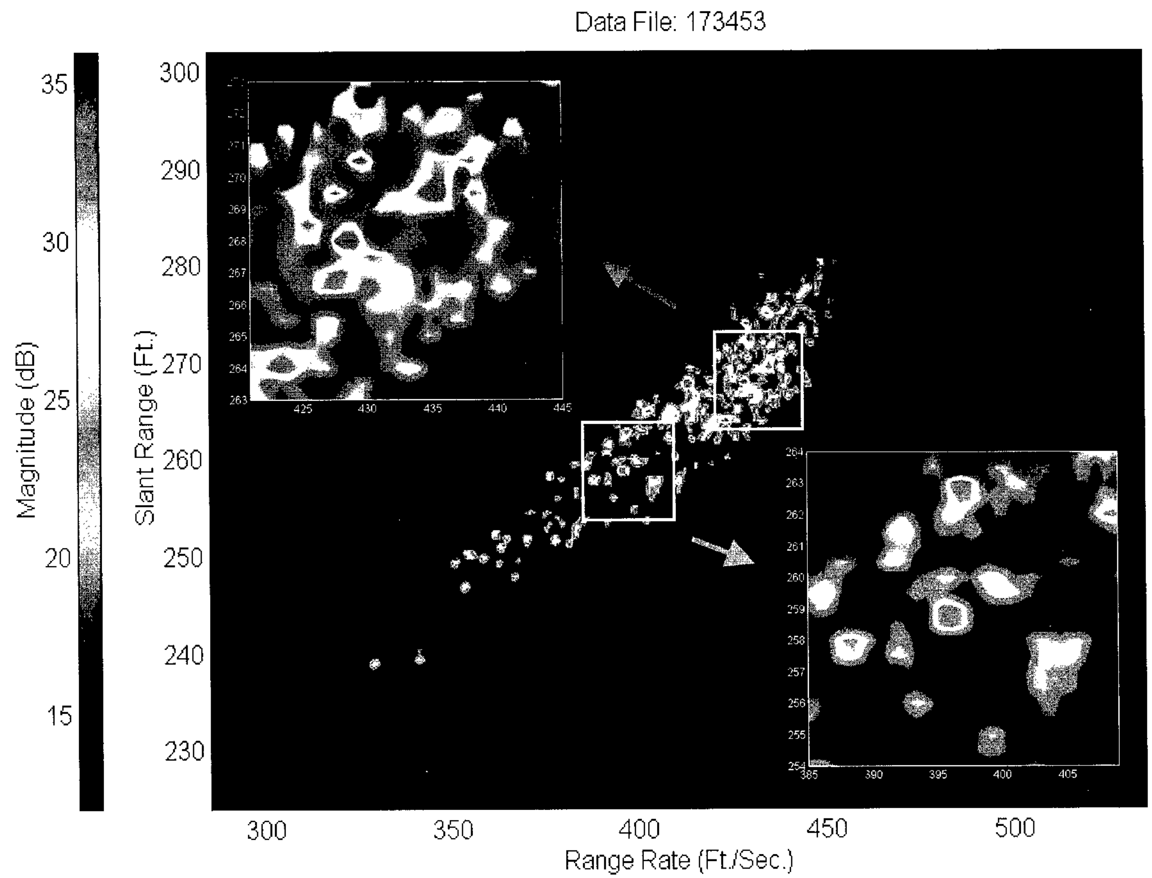


Noise Radar Seeker

- Features: Extremely High Bandwidth, Jam Resistant, No Ambiguities
- Reduced Requirements: Antenna Sidelobes, H/W Stability, 1 Bit A/D
- Challenge: Signal Processor



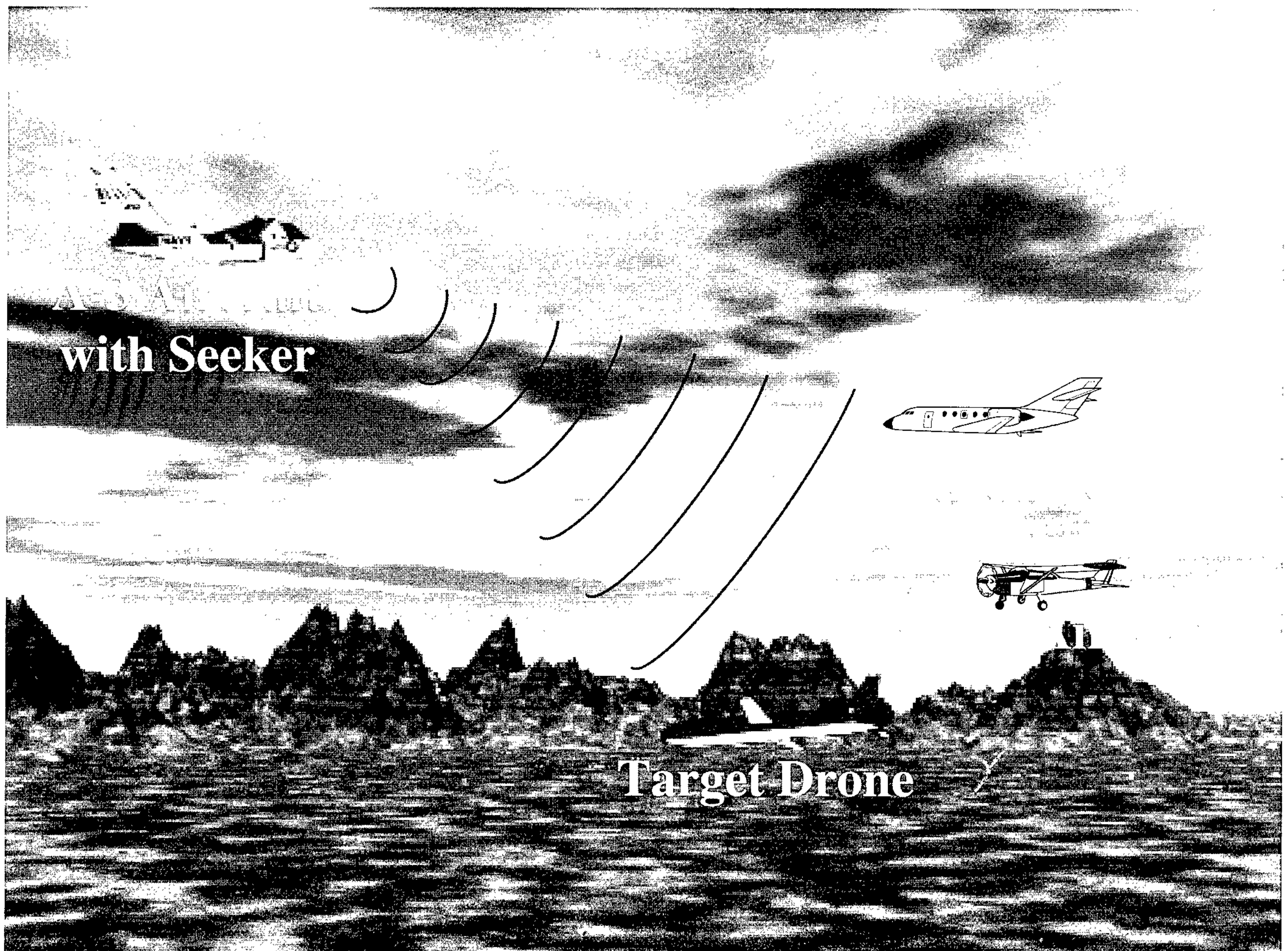
Noise Radar Imaging



DARPA

SPO

Flight Test



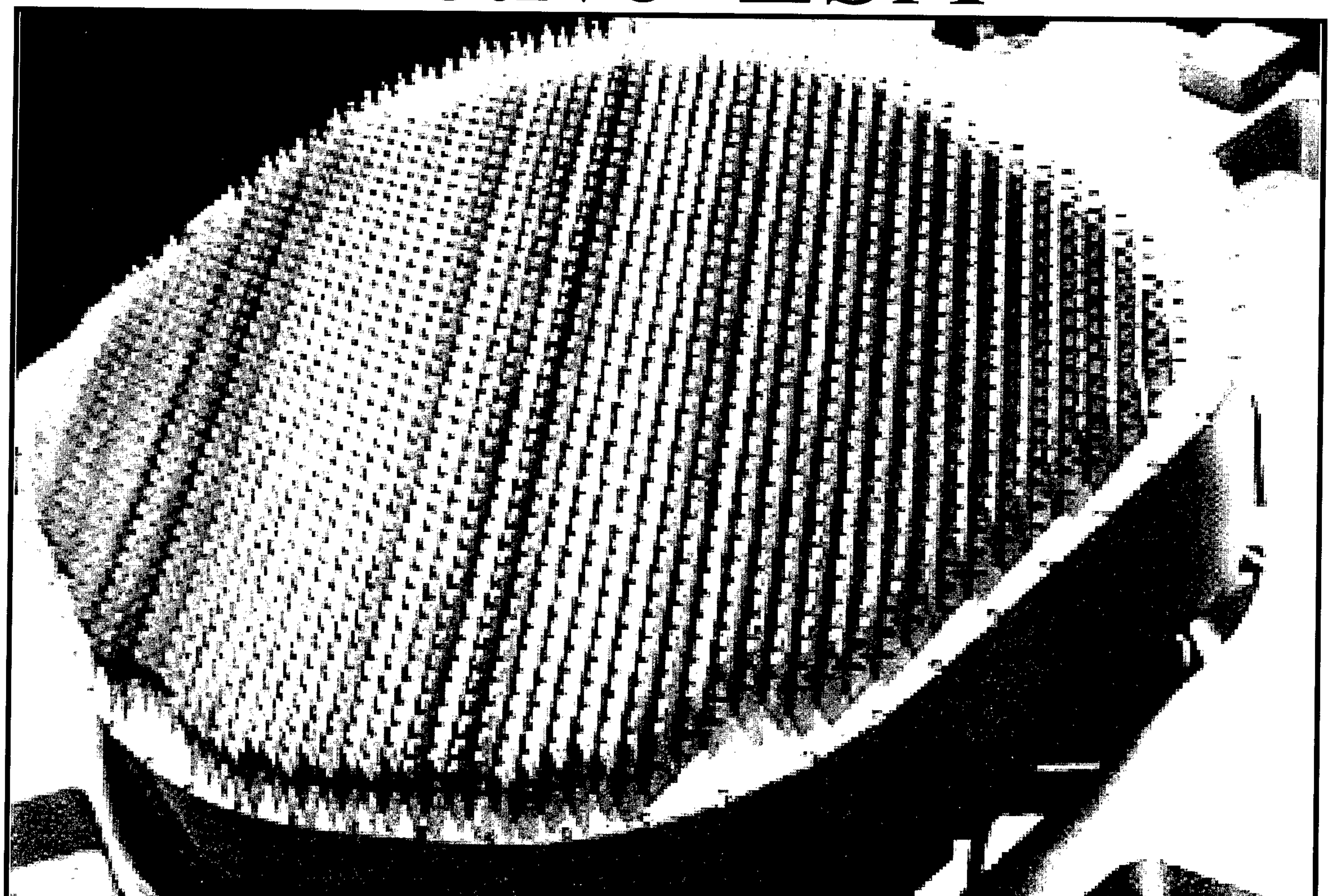
Summary

- Program Addresses a Threat that Can Quickly Emerge
- Program Pursuing 6 Promising Concepts
  - Two Radar Seekers
  - Two Infrared Seekers
  - Two Novel Antennas
- We Continue to Look for More Novel Approaches to Cruise Missile Defense and Technologies that Enable Multi-Mission Applicability

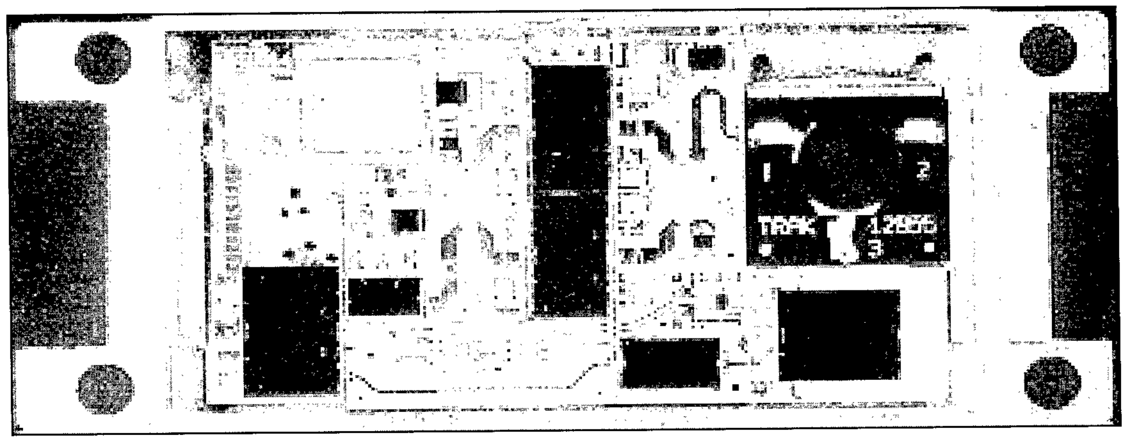
MEMS And Advanced Radar

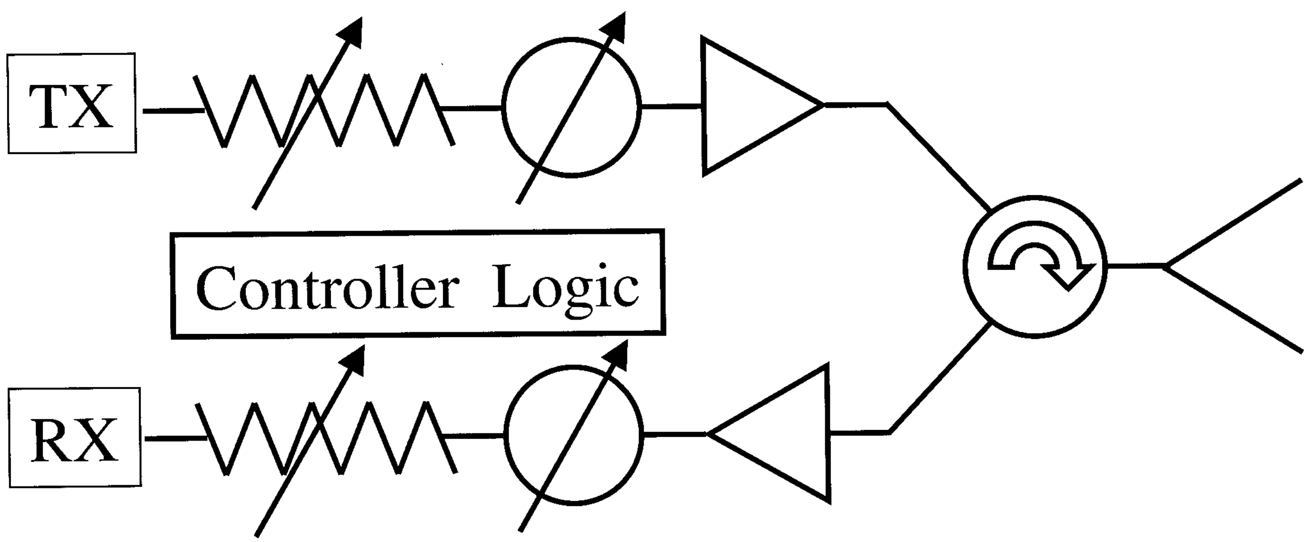
Dr. John K. Smith

Active ESA



T / R Module



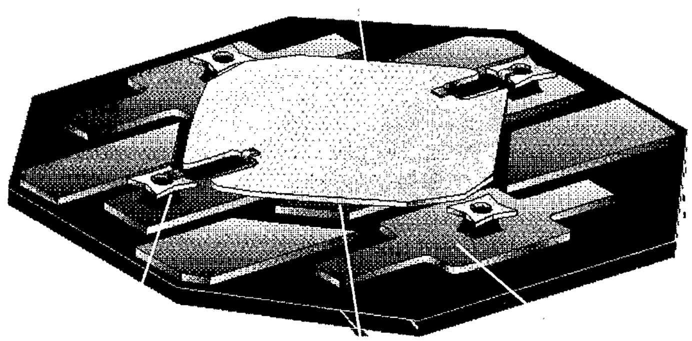


DARPA

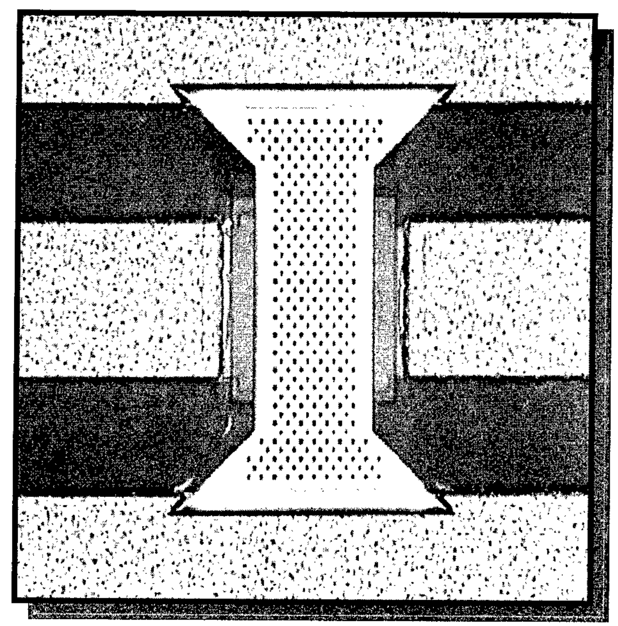
MEM RF Switch

SPO

Digital Mirror Device



Shunt Bowtie Switch

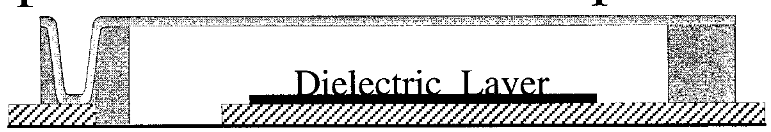


DARPA SPO

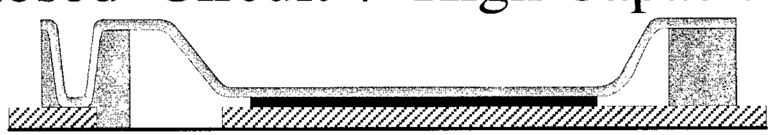
MEM Switch

- Controlled By Static DC Voltage
- Acts As RF Switch Or Capacitor

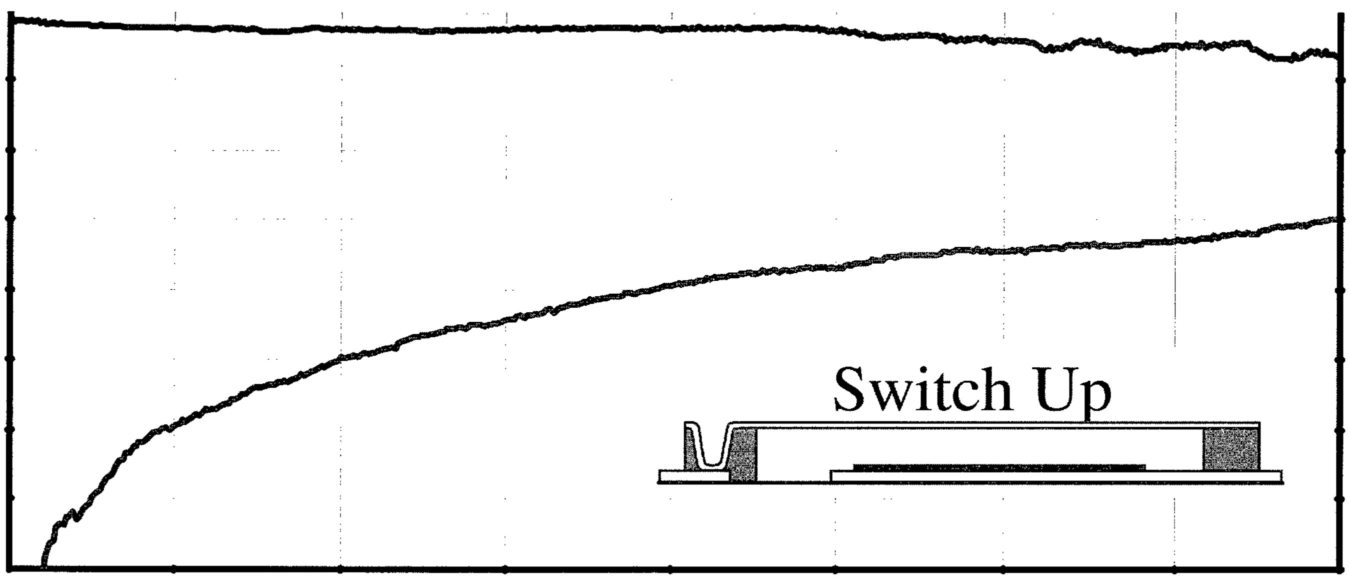
Open Circuit / Low Capacitance



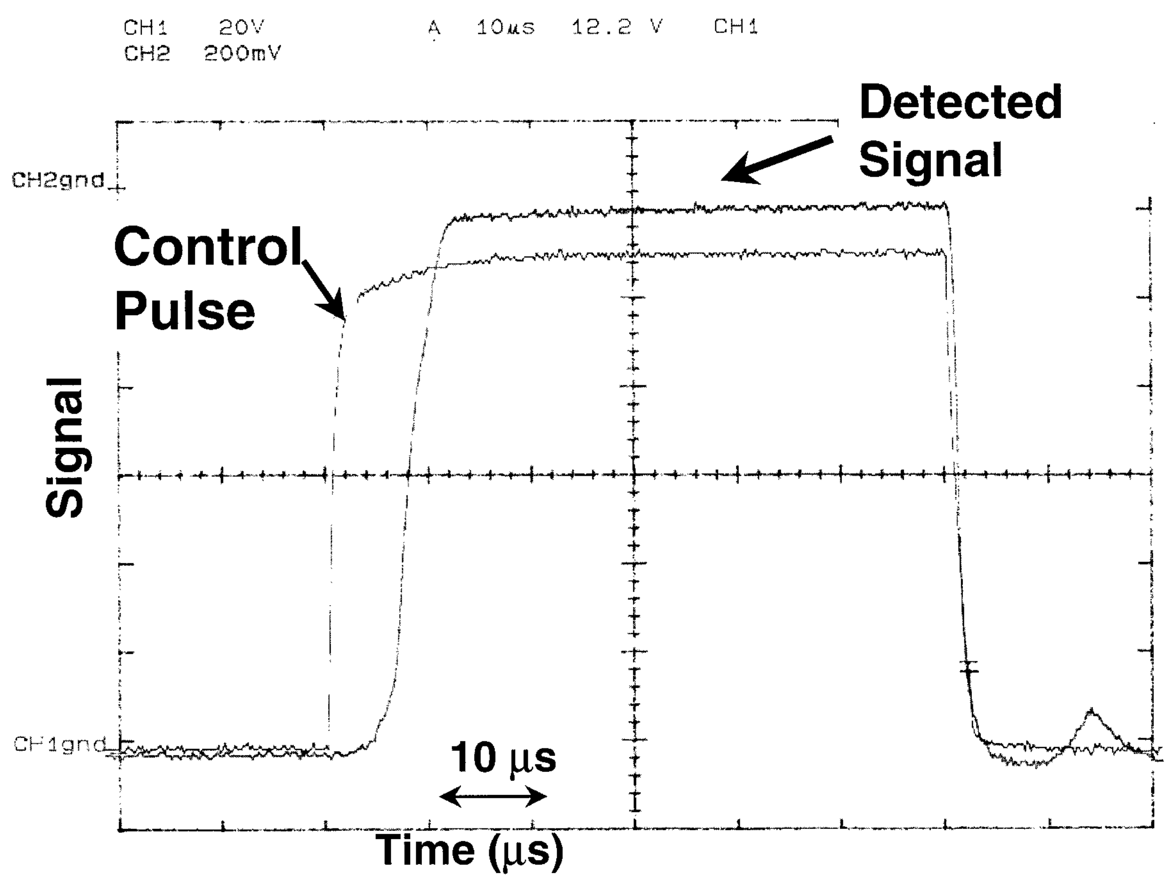
Closed Circuit / High Capacitance



RF Performance



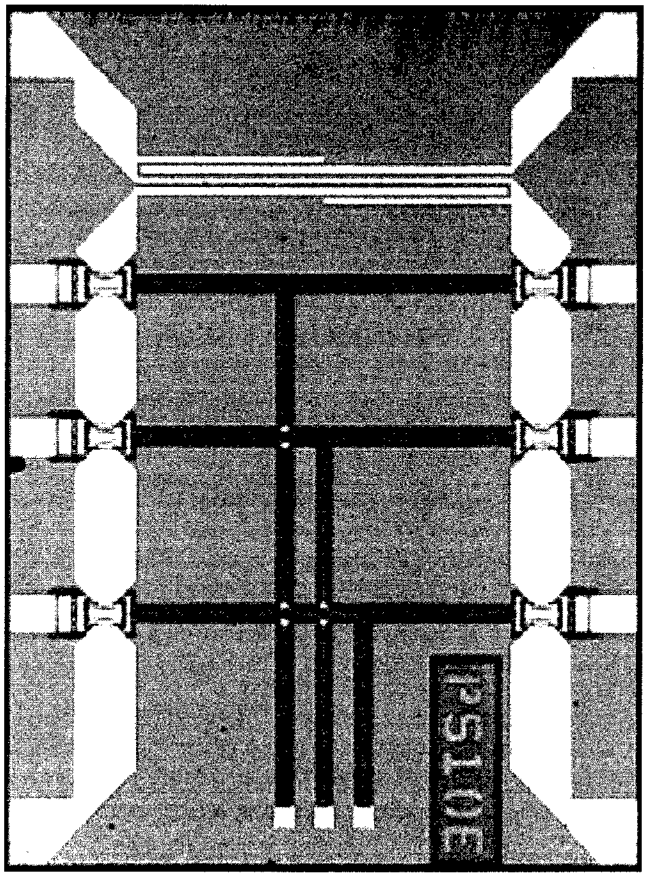
Switching Time



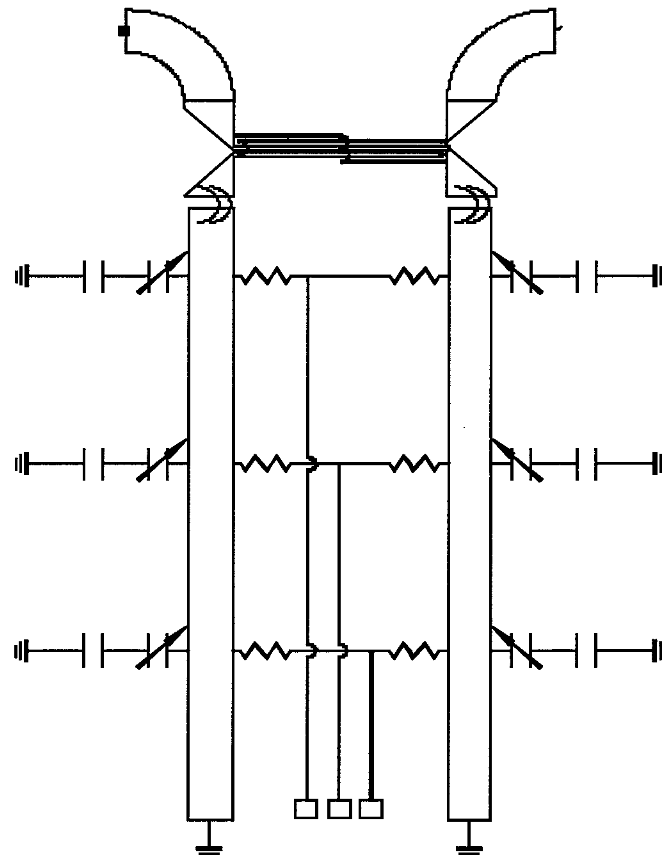
DARPA

SPO

X-Band Phase Shifter



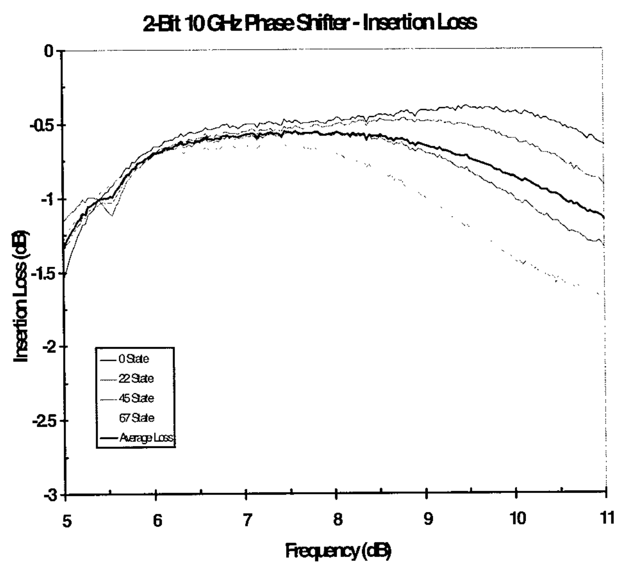
Photograph

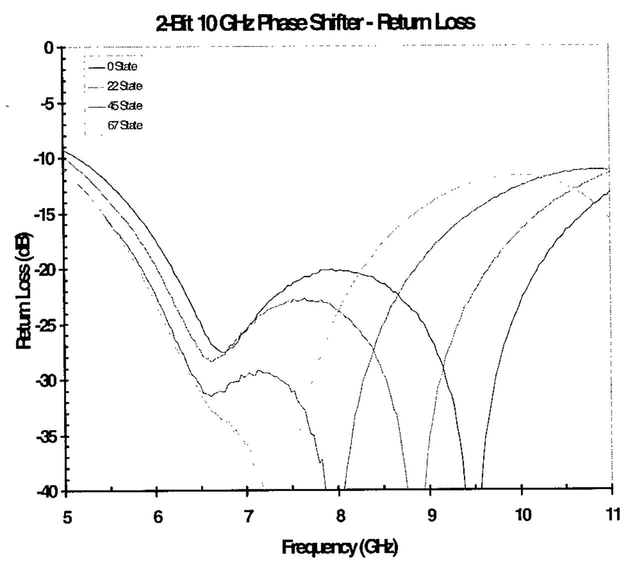


Schematic

Measured Characteristics

10 GHz 2-Bit (Small) PS Performance





<u>6.0 - 10.0 GHz</u>

- Average insertion loss 0.55-0.9 dB (Arithmetic average of all 4 states)

<u>5.5 - 11.0 GHz</u>

- Return loss > 11 dB

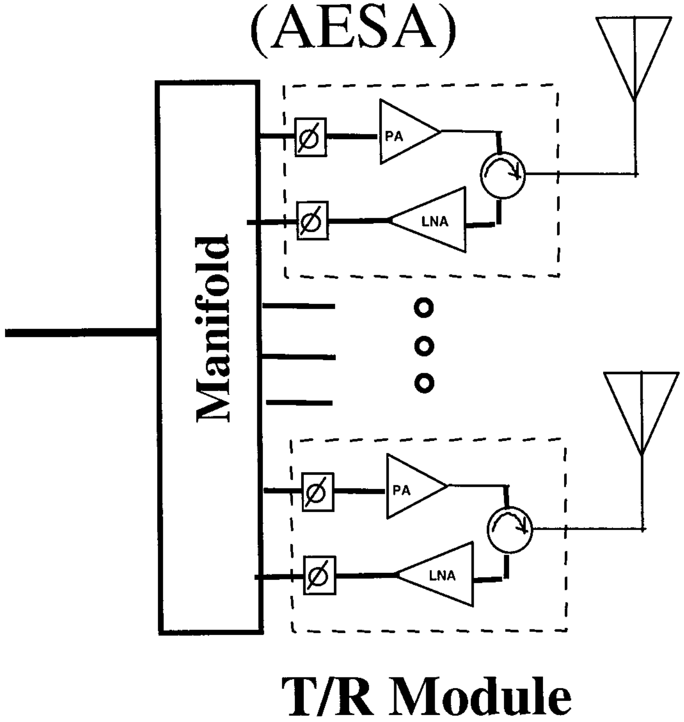
Phase Shifter Technologies

Typical 4 Bit X-Band

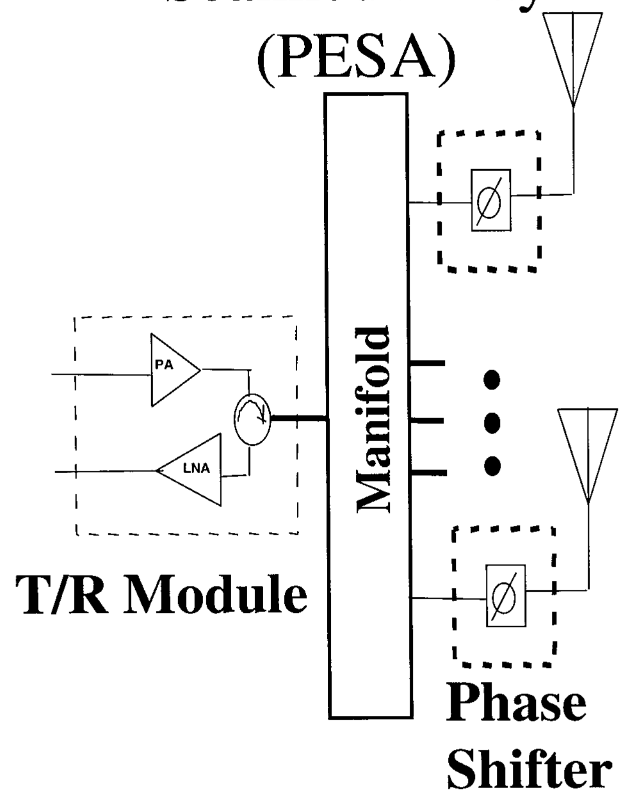
Technology	Unit Cost	Power	Loss
MEMS	$10	1 mw	1.5 dB
GaAs MMIC	$40	20 mw	6-8 dB
Ferrite	$100	400 mw	1.2 dB
Diode	$20	200 mw	2.0 dB

AESAs And PESAs

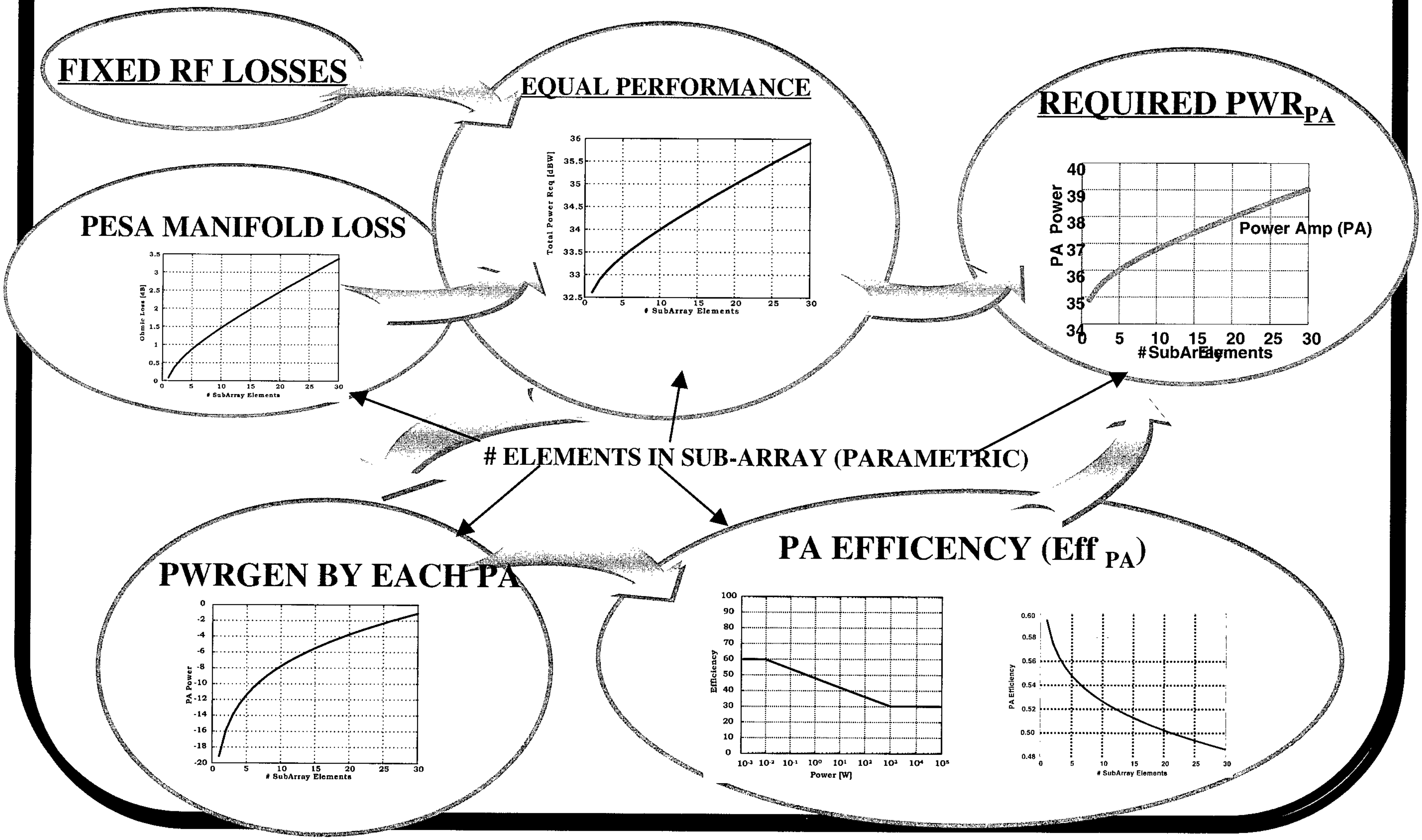
Active Electronically Scanned Array (AESA)



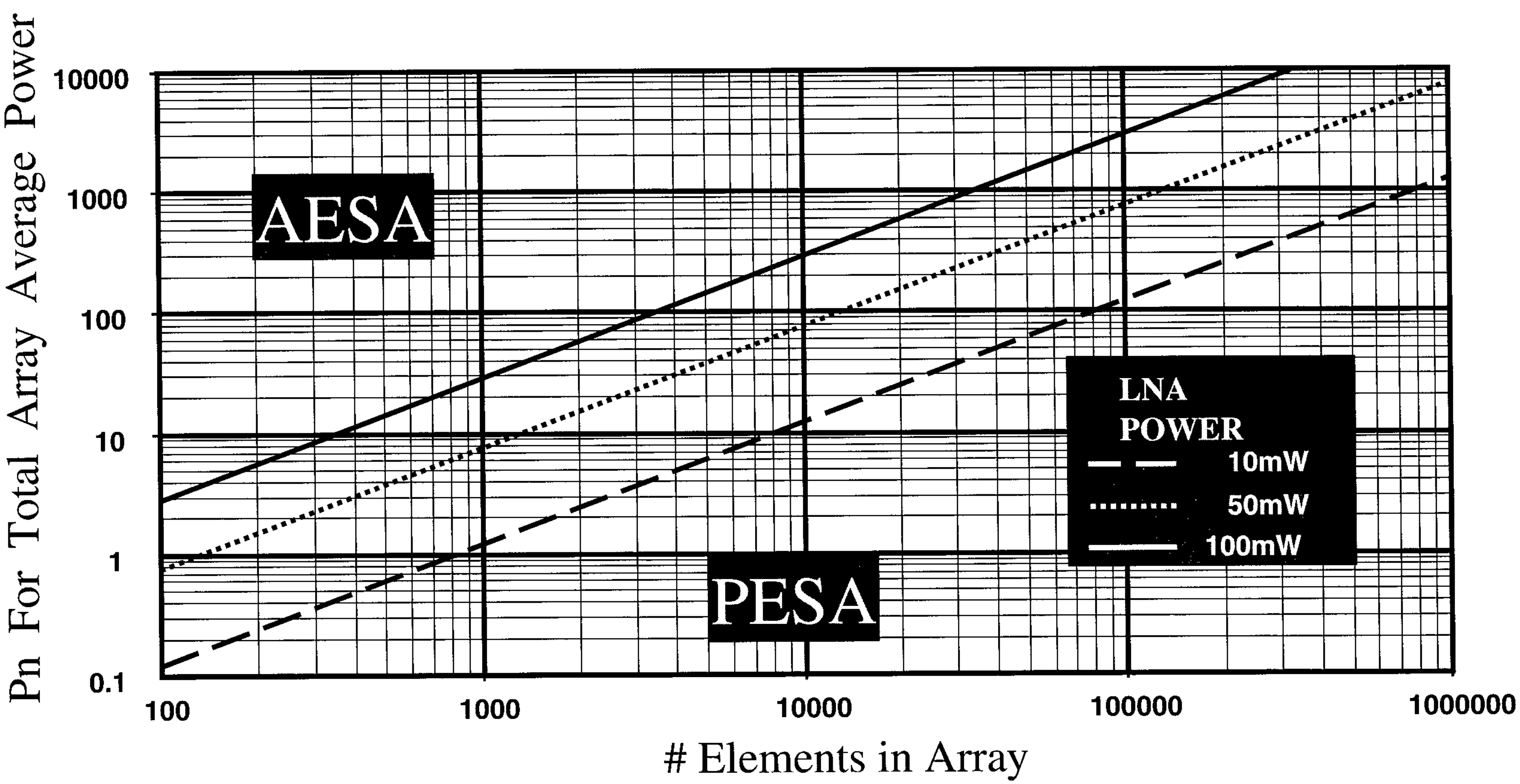
Passive Electronically Scanned Array (PESA)



Transmitter Power Trades



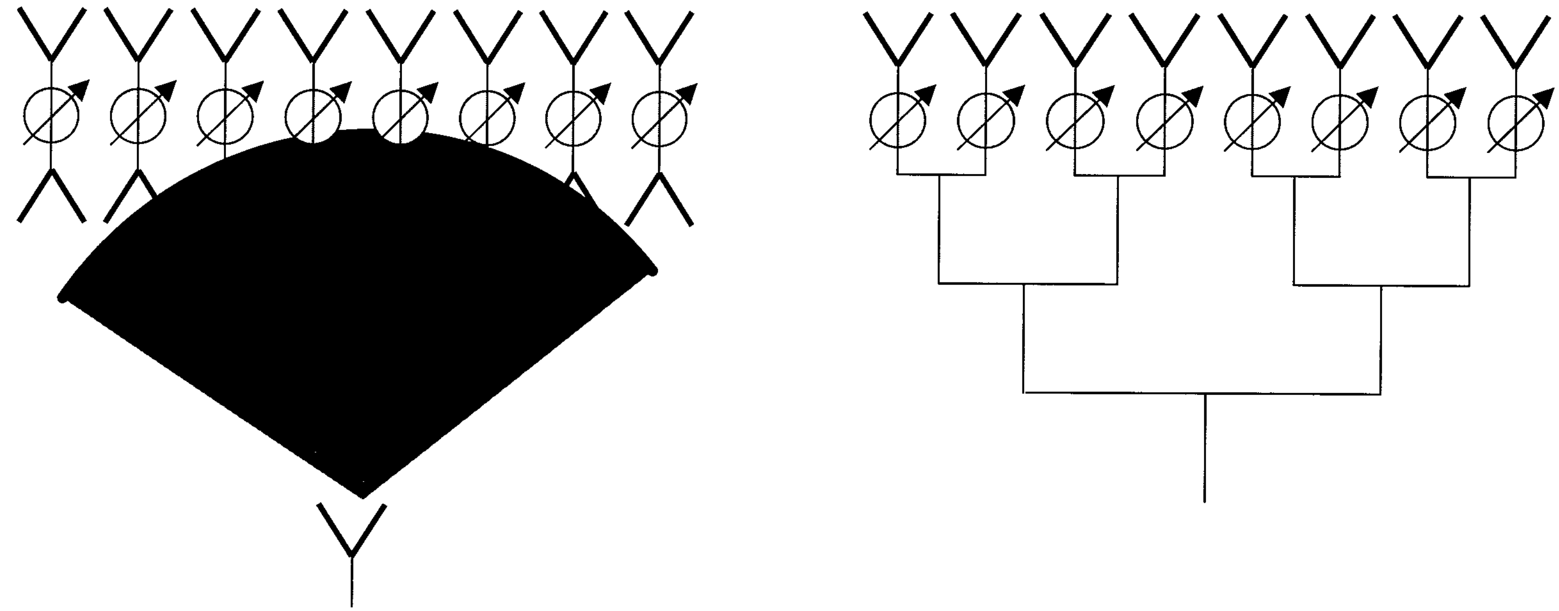
Array Size And MEM's Advantage



MISSILES AI AIRBORNE SURVEILLANCE AERO STAT SBR

DARPA SPO

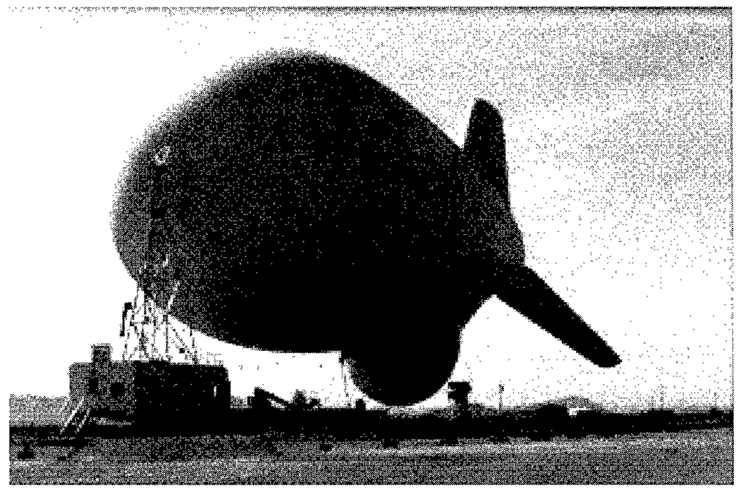
Space Fed Lens Vs. Constrained Feed



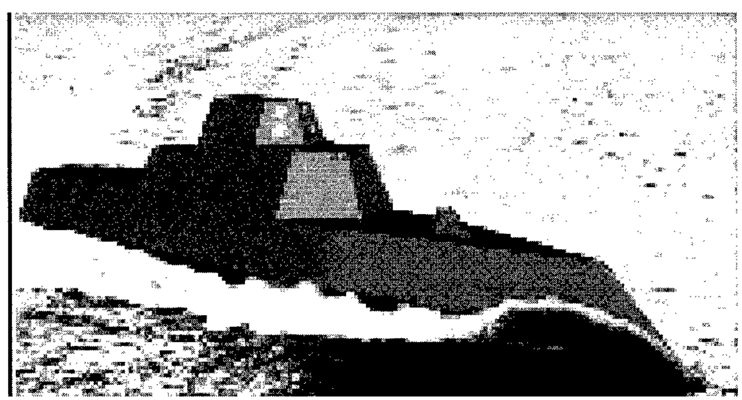
	Space	Constrained
Cost	Low	High
Weight	Low / Med	Med / High
Bandwidth	Low	Med / High

Space - Fed Lens Applications

- Aerostat



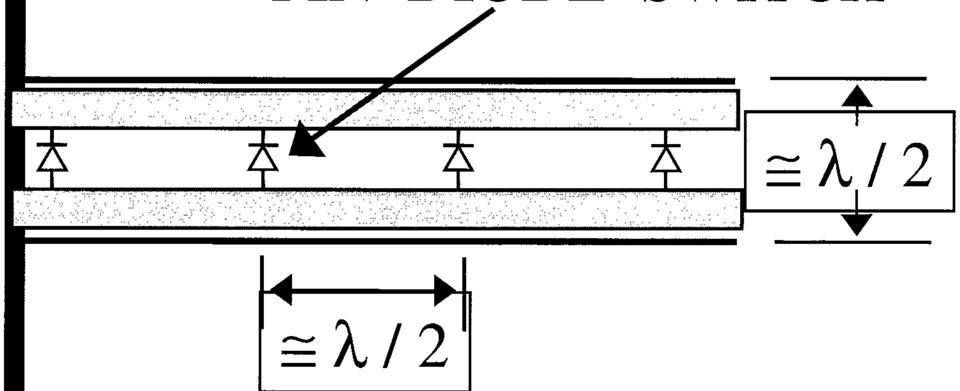
- Ship

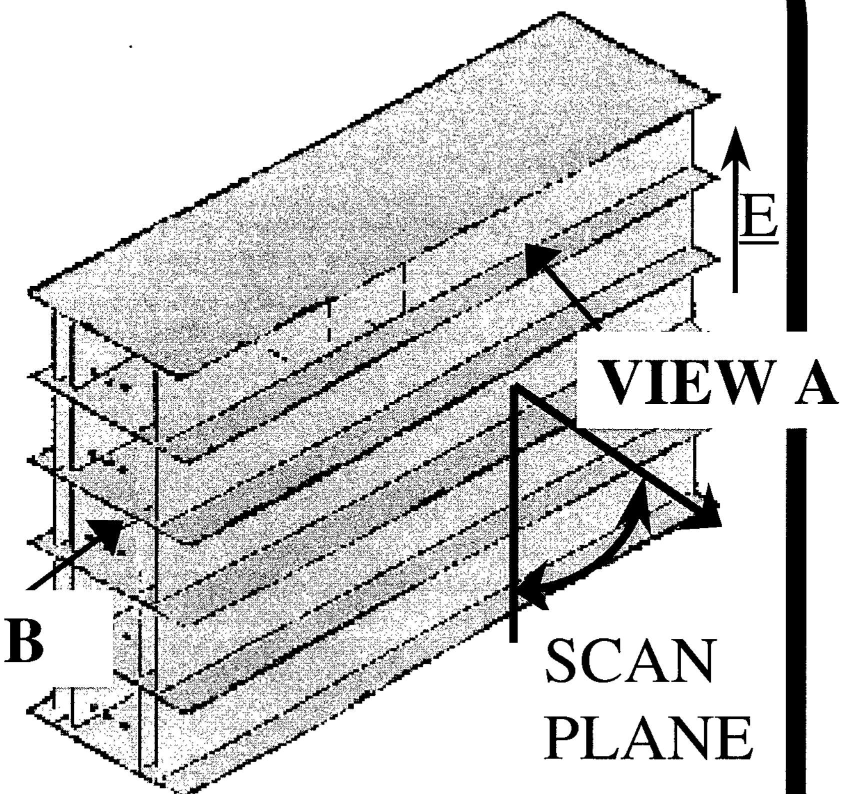


Radant™ Lens

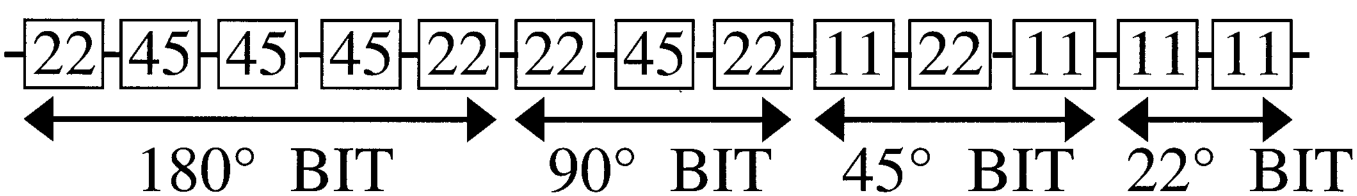
VIEW A

PIN DIODE SWITCH

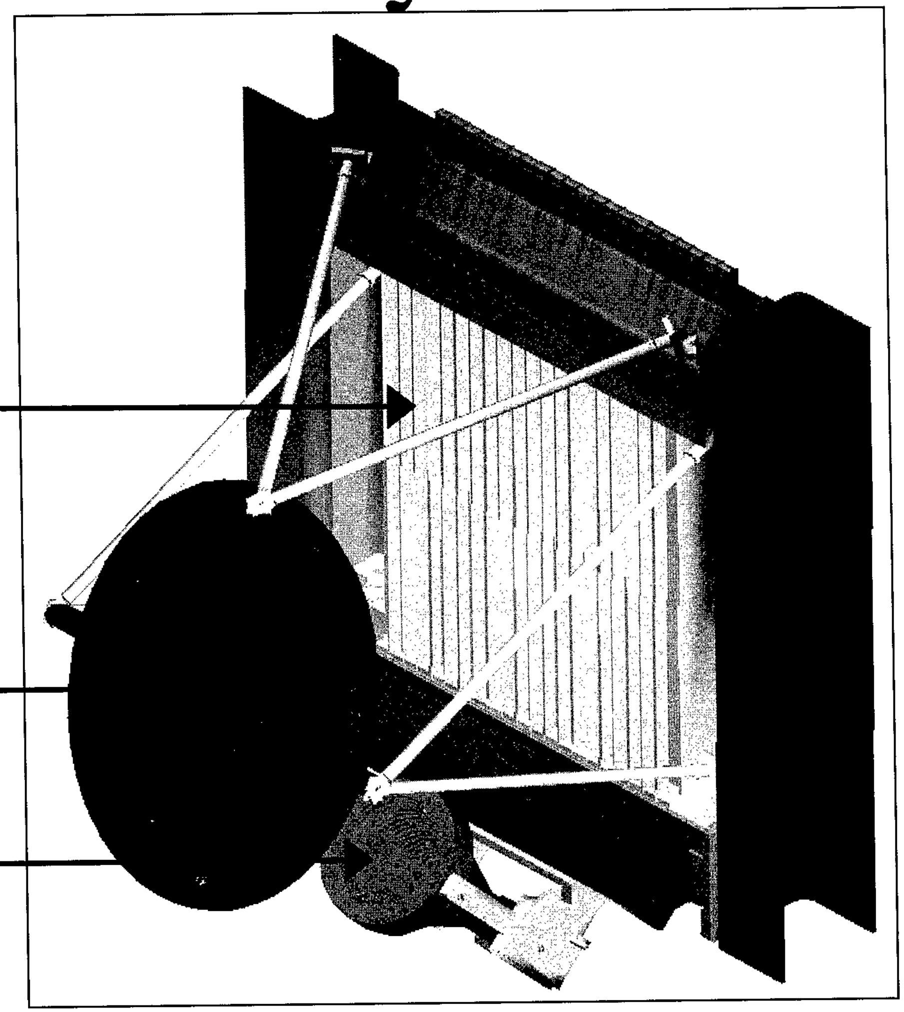




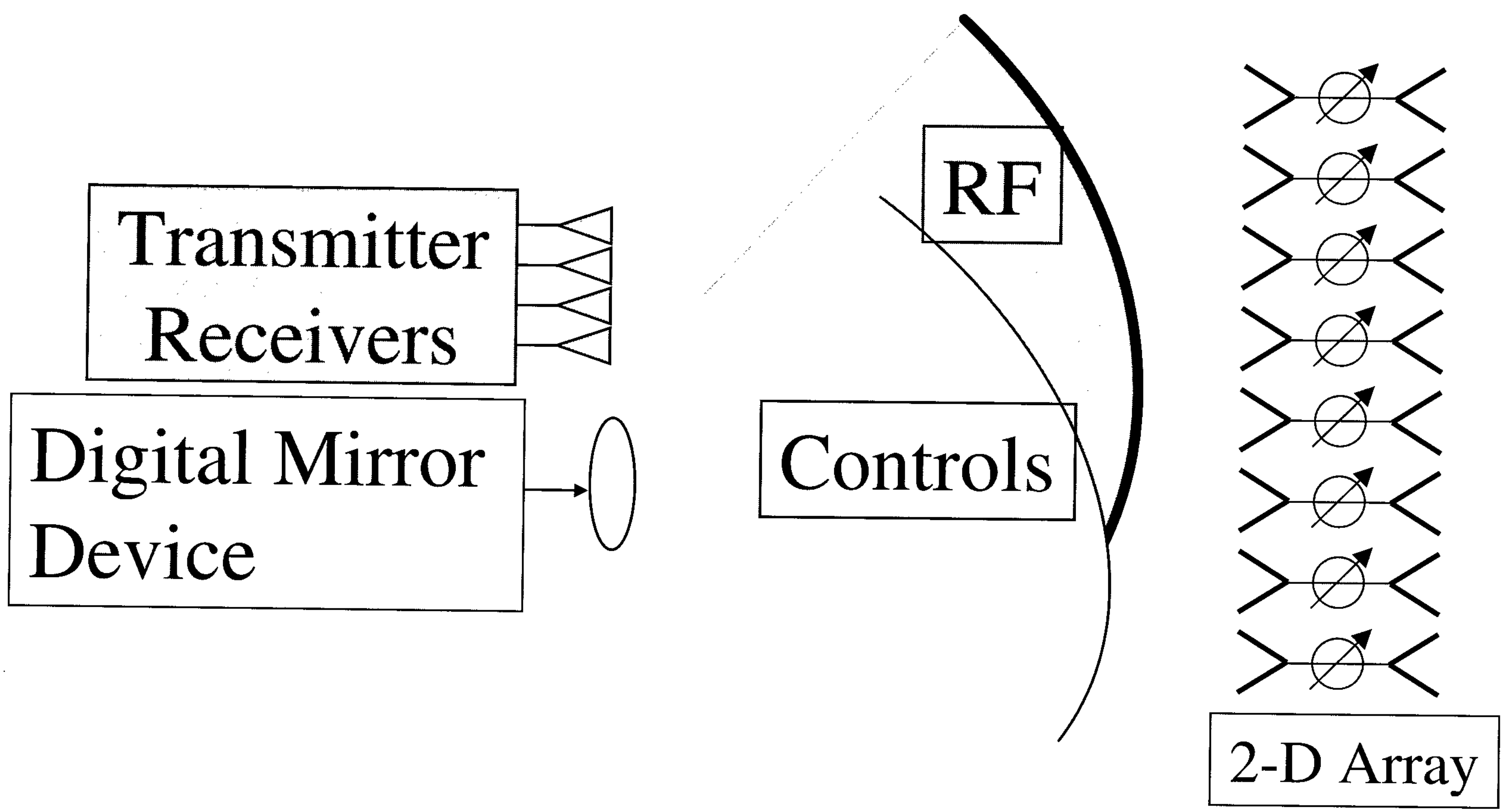
VIEW B



Experimental System



MEM-Tenna



Transmitter
Receivers
Digital Mirror
Device
RF
Controls
2-D Array

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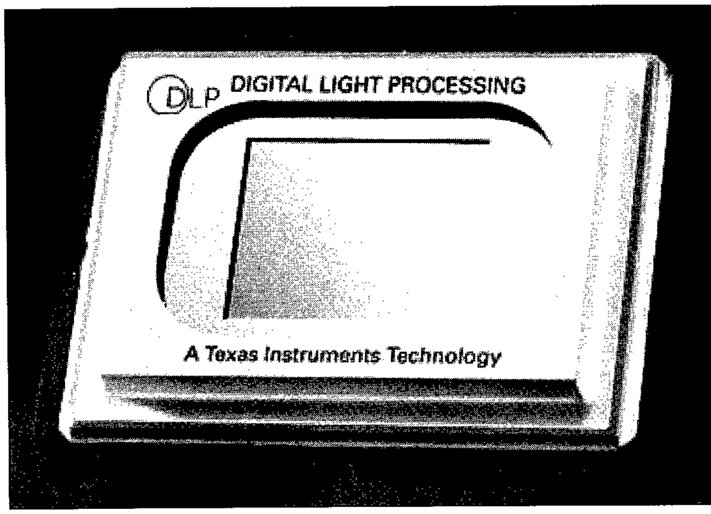
Digital Mirror Device



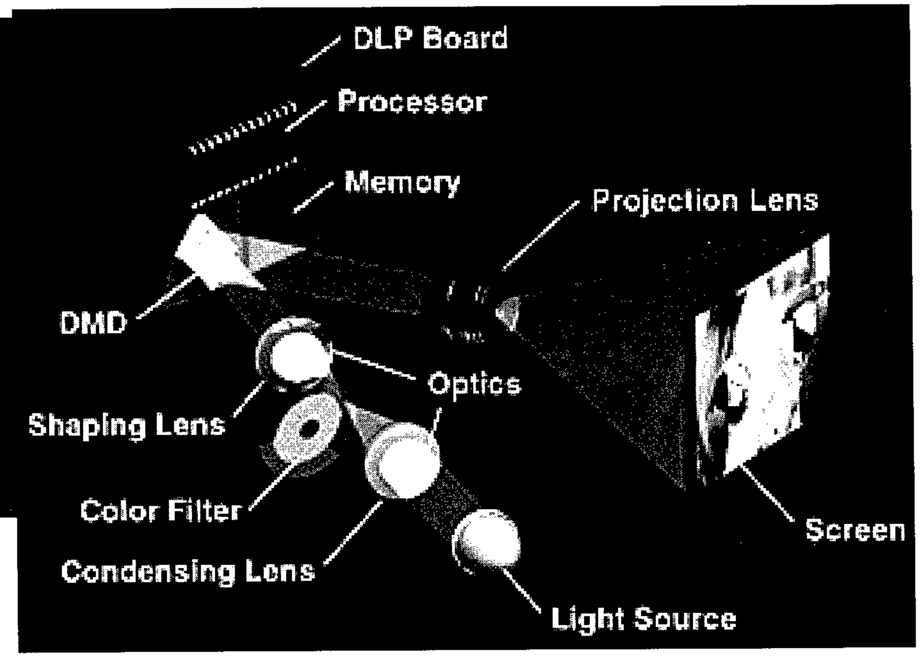
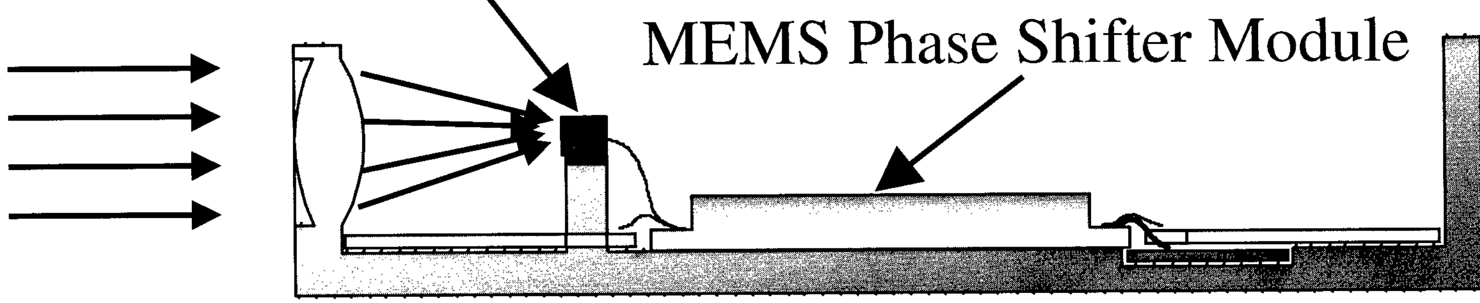
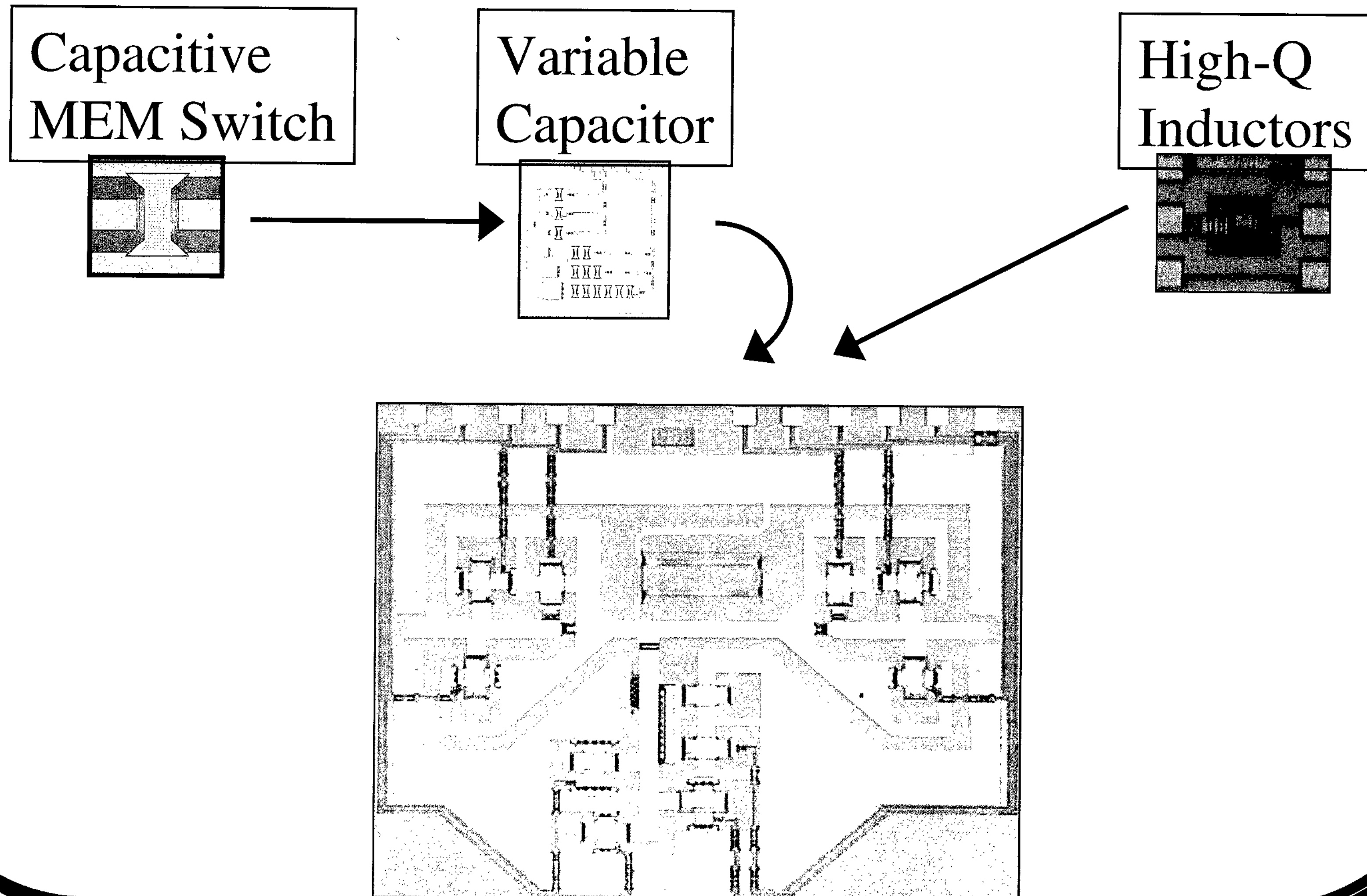


Photo Detector Diode

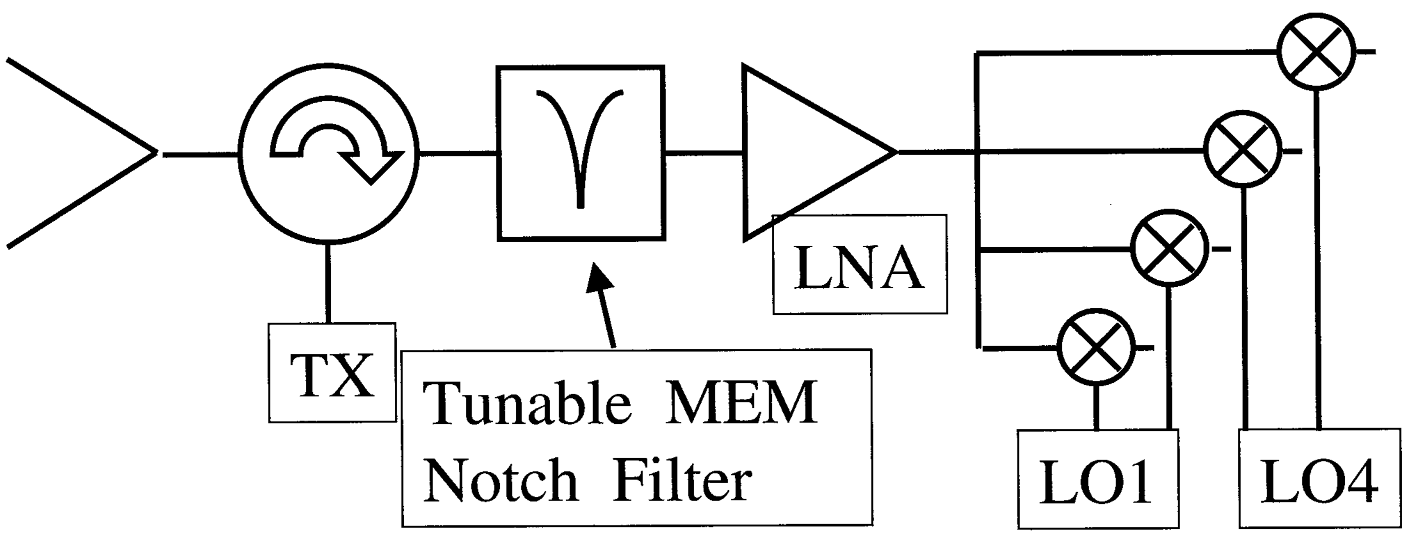
MEMS Phase Shifter Module



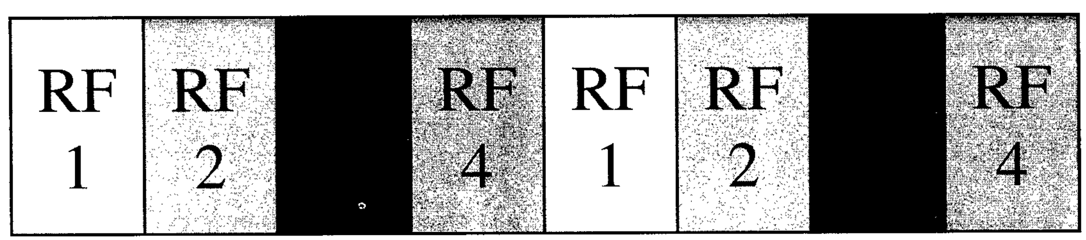
MEM Tunable Filter



STAR Waveform



PRI



Tx 1 Receive 1

STAR and Radar

- Range And Velocity Eclipsing Reduction
- Frequency Diversity
- Interleaved Waveforms: SAR/GMTI
- Multiple Beams
- Data Links In Common Aperture
- A/G And A/A Mode Interleaving

Conclusions

- MEMs Phase shifters and filters revolutionize radar antennas
  - Space feeds: MEM-Tenna
  - STAR Waveforms
- Order of magnitude reduction in cost and weight is possible

Sensor Exploitation Programs

Dr. Thomas M. Strat
Special Projects Office

ISO Organization

[redacted]

Sensor
Exploitation

[redacted]

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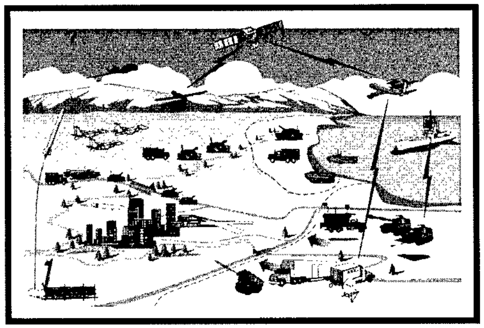
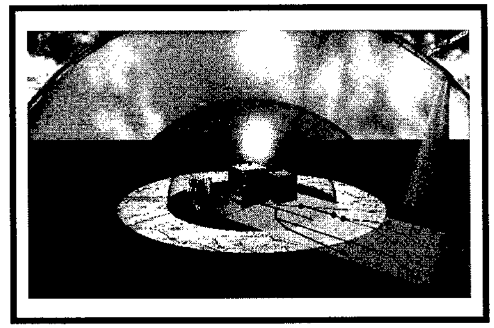
Operational Problems

Force-on-Force



- Detect, track, identify military forces
- Terrain extraction and analysis
- Broad area search

Asymmetric Warfare



- Detect, track, identify potentially hostile human activities
- 3-D model construction
- Site monitoring

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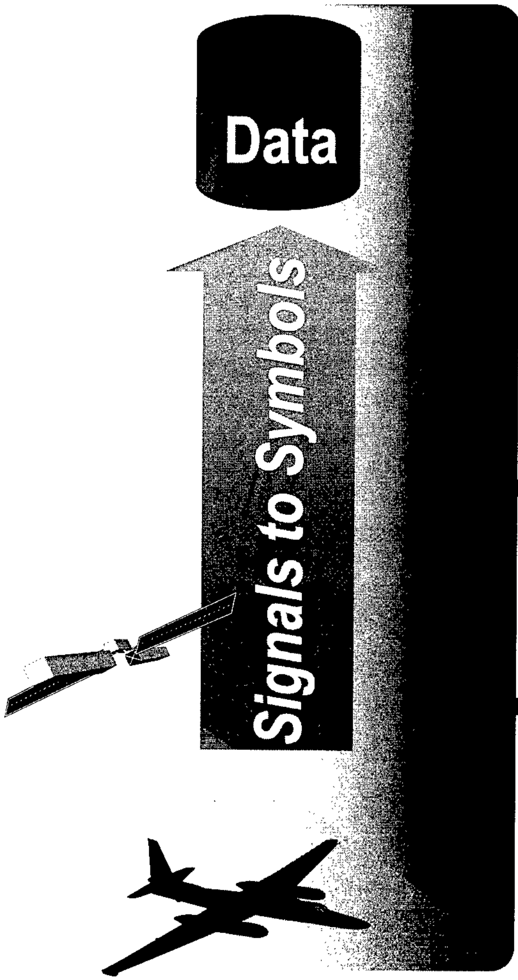
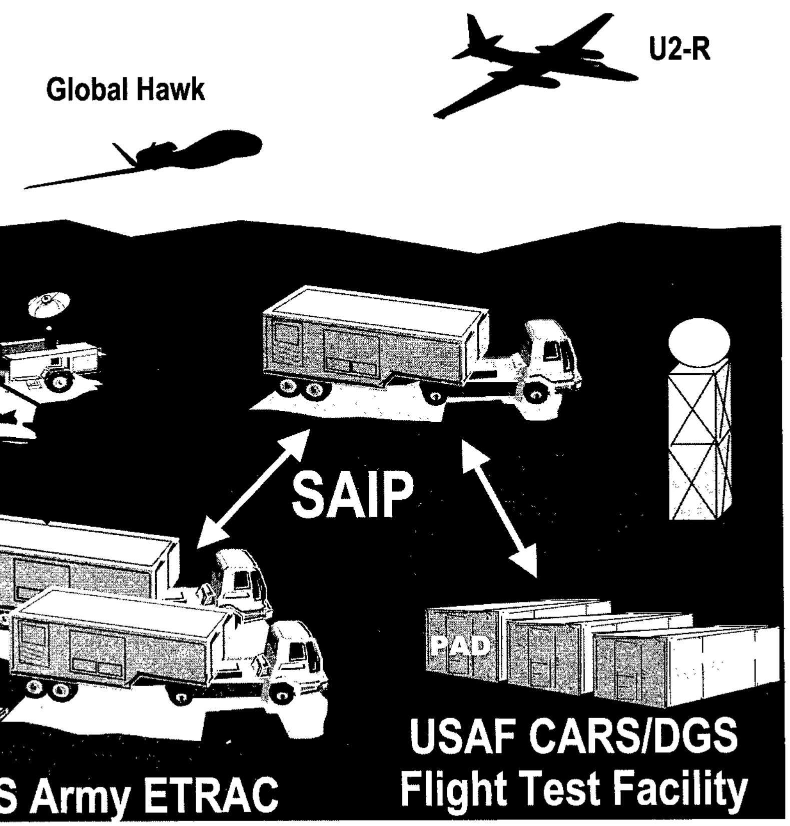
Sensor Exploitation Themes



Automatic Recognition	MSTAR AVS IUFP
Multisensor Exploitation	DDB
Sensor Management	AIM
Exploitation Systems	SAIP

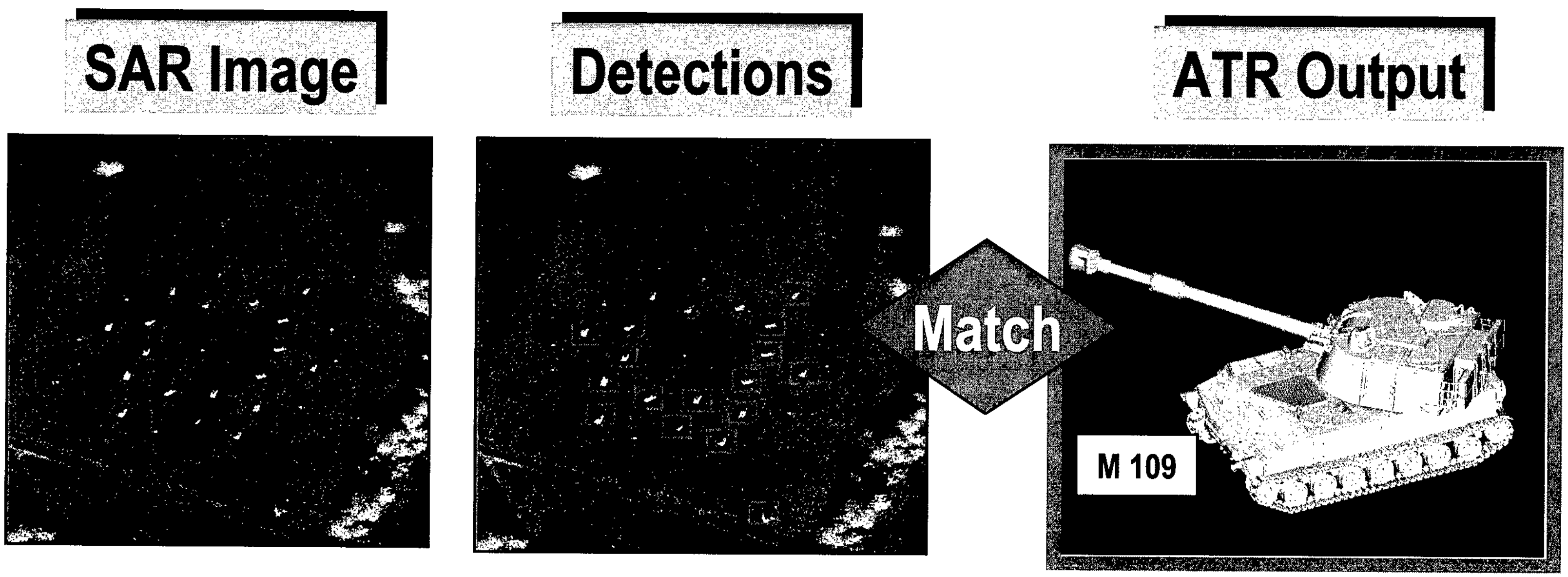
Semi-Automated IMINT Processing

An operational demonstration delivering a ten-fold improvement in tactical SAR exploitation rates



Next Generation ATR: MSTAR

Better ATR through model based technology



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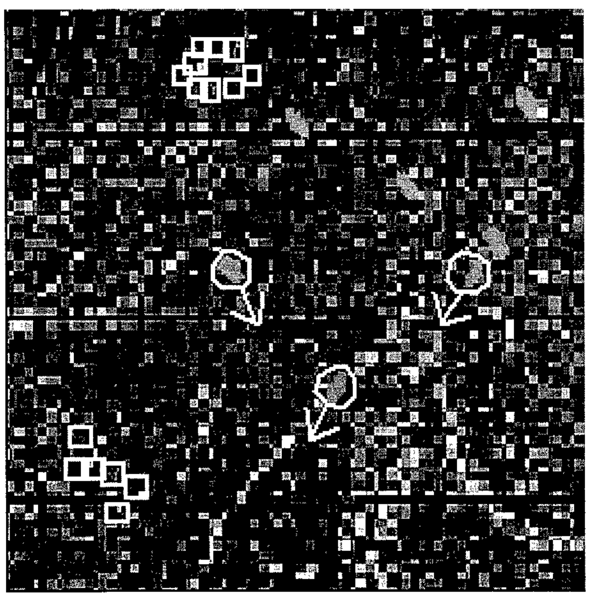
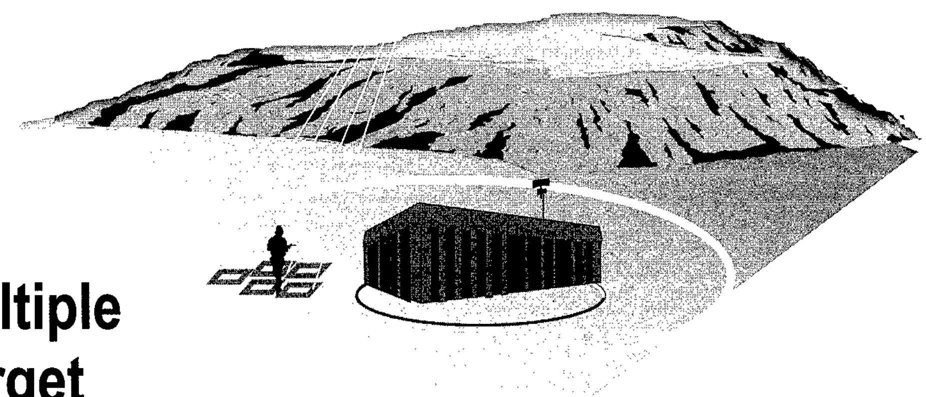
Airborne Video Surveillance

Technology to make video more useful: A UAV force multiplier

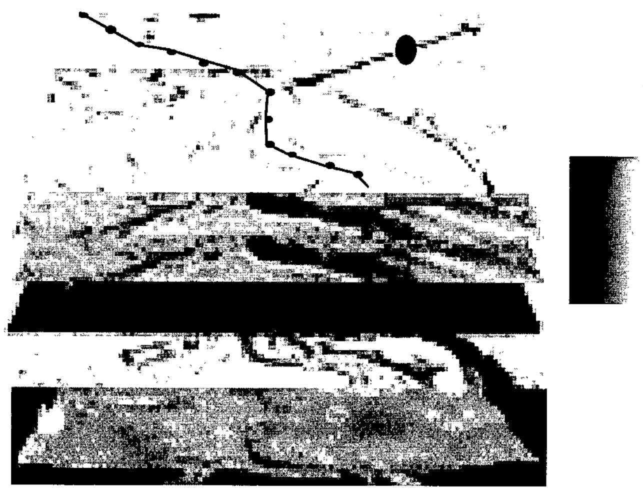


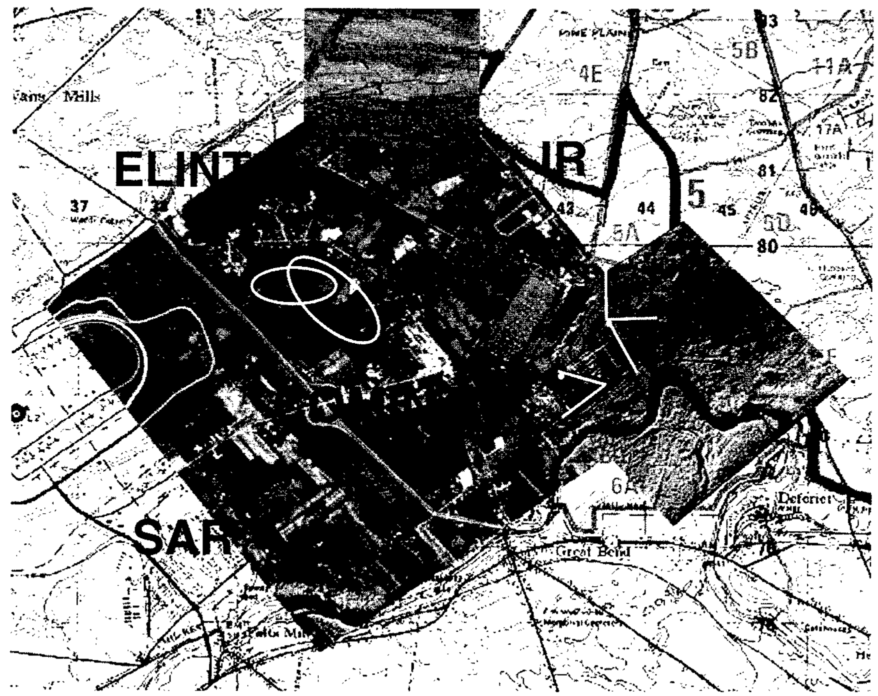
Multiple Target Surveillance



Dynamic Database

Dynamic situation awareness through multi-sensor exploitation





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Advanced ISR Management

Optimizing ISR support to the dynamic battlefield

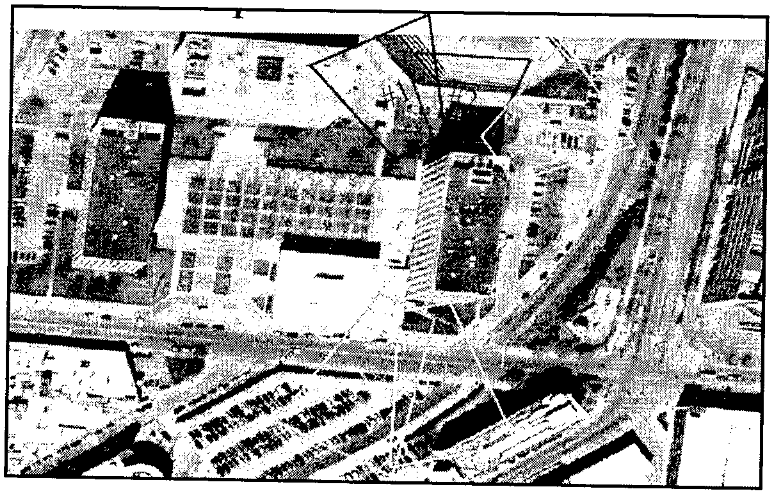
Information Needs
(Derived)

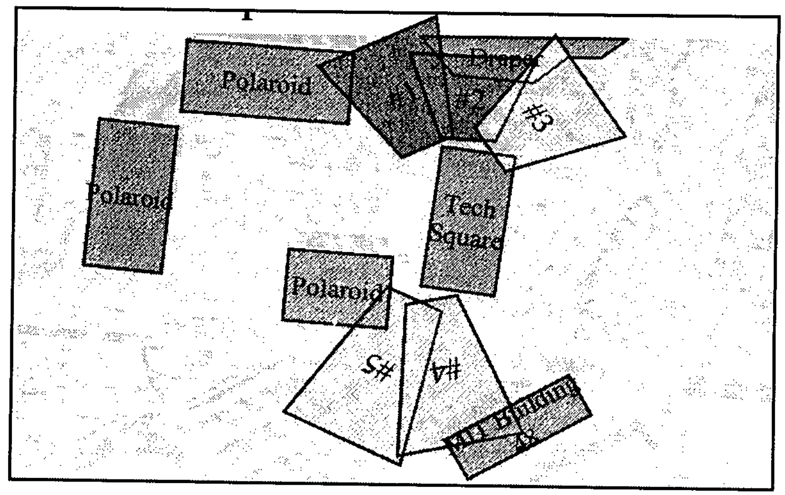
Collection Tasks
(Coordinated)

Processing Tasks
(Cooperative)

Image Understanding for Force Protection

Information systems that see and understand in urban environments





BAA's

AIM

Advanced ISR Management

IUFP

Image Understanding for Force Protection

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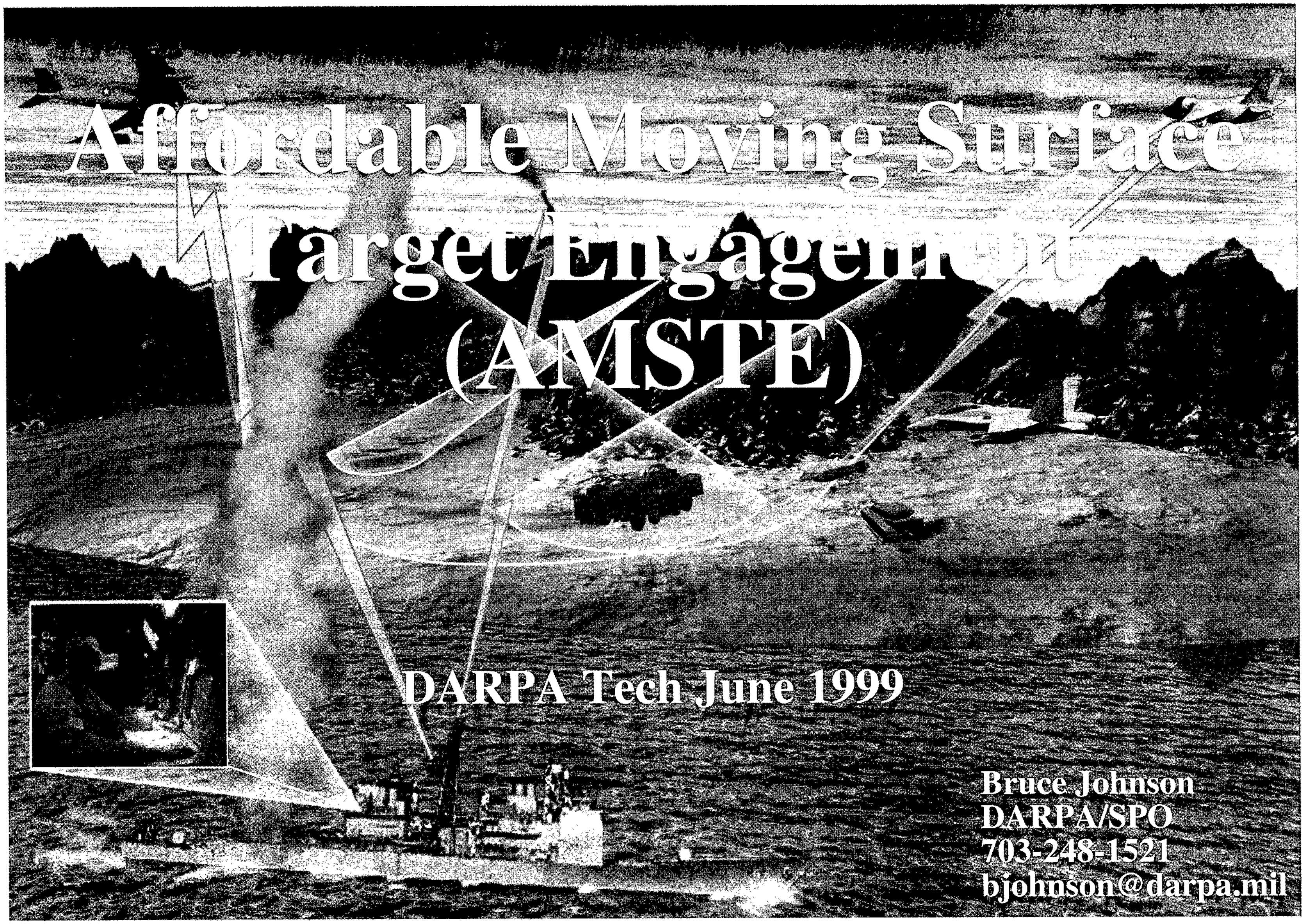
Sensor Exploitation Challenges

Vehicle-centric	→ *Human-centric*
Stovepiped analysis	→ *Multisensor exploitation*
Passive exploitation	→ *Active sensor management*

- Increase levels of automation
- Invent new ways to exploit data


Affordable Moving Surface
Target Engagement
(AMSTE)
DARPA Tech June 1999
Bruce Johnson
DARPA/SPO
703-248-1521
bjohnson@darpa.mil

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SPO

Outline

- Motivation
- AMSTE Concept
- Feasibility Study
- AMSTE Program
- Summary

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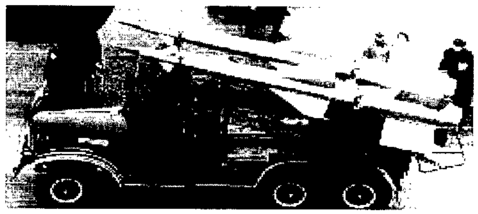
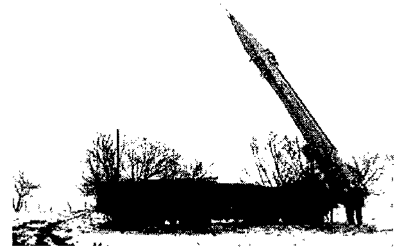
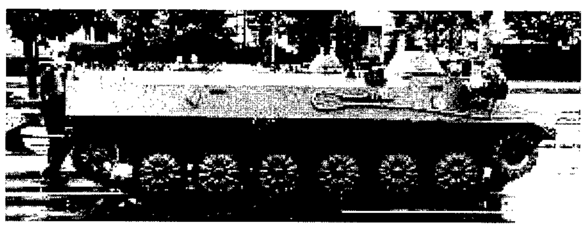
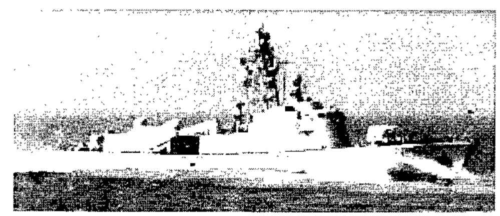
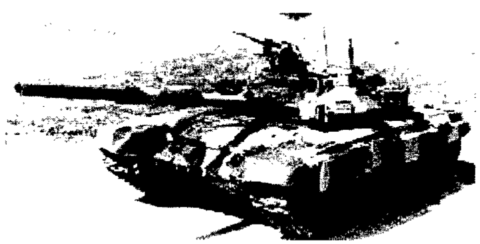
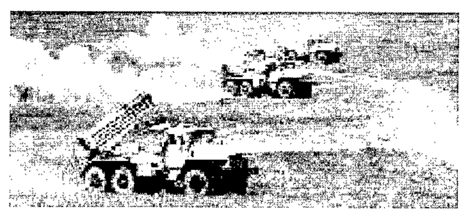
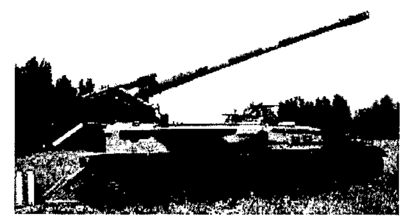
Motivation

- Affordably destroying moving surface targets is an essential future capability
- Existing approaches:
  - –Sophisticated sensors
  - –Man in the loop
  - –Dispersive munitions

Mobile Targets

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Observation

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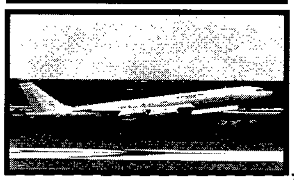
Modern technology provides basis for the *affordable* precision targeting of moving surface targets

- Planned GMTI sensors
- Precision weapons
- Communication networks
- High performance processing

GMTI Systems

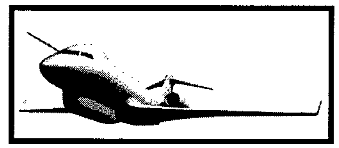
U-2

ARL

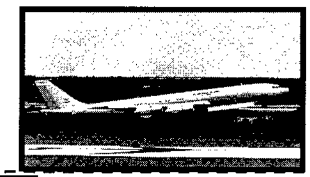


JSTARS

Manned Aircraft:
- Stand-off, look in
- Large payload
- Multifunction capabilities
- On-board BM/C3



ASTOR (UK)



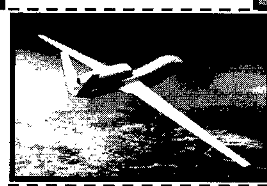
RTIP JSTARS

Fighter MTI

APG-73
APG-76
APG-68
JSF

Others:
- Tactical UAV
- Special platforms

Global Hawk

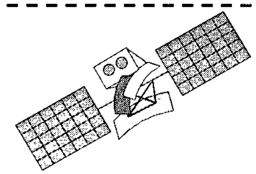


Unmanned Aircraft:
- Penetrating
- Multifunction capabilities
- Low Cost

Space based:
•world wide access
•peace & war
•ground BM/C3

DISCOVER II
MTI demo

Space Based MTI?



1990 2000 2010 2020

Precision Weapons

- Extended Range Guided Munition
- Joint Direct Attack Munition
- Joint Stand Off Weapon
- Joint Air to Surface Standoff Missile
- Small Smart Bomb
- Tomahawk Land Attack Missile
- Tactical Tomahawk

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AMSTE Concept

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- Network GMTI sensors
  - –Improve detection
  - –Increased revisit rate
  - –Reduced location errors
- Precision fire-control tracking
- Command guided weapons

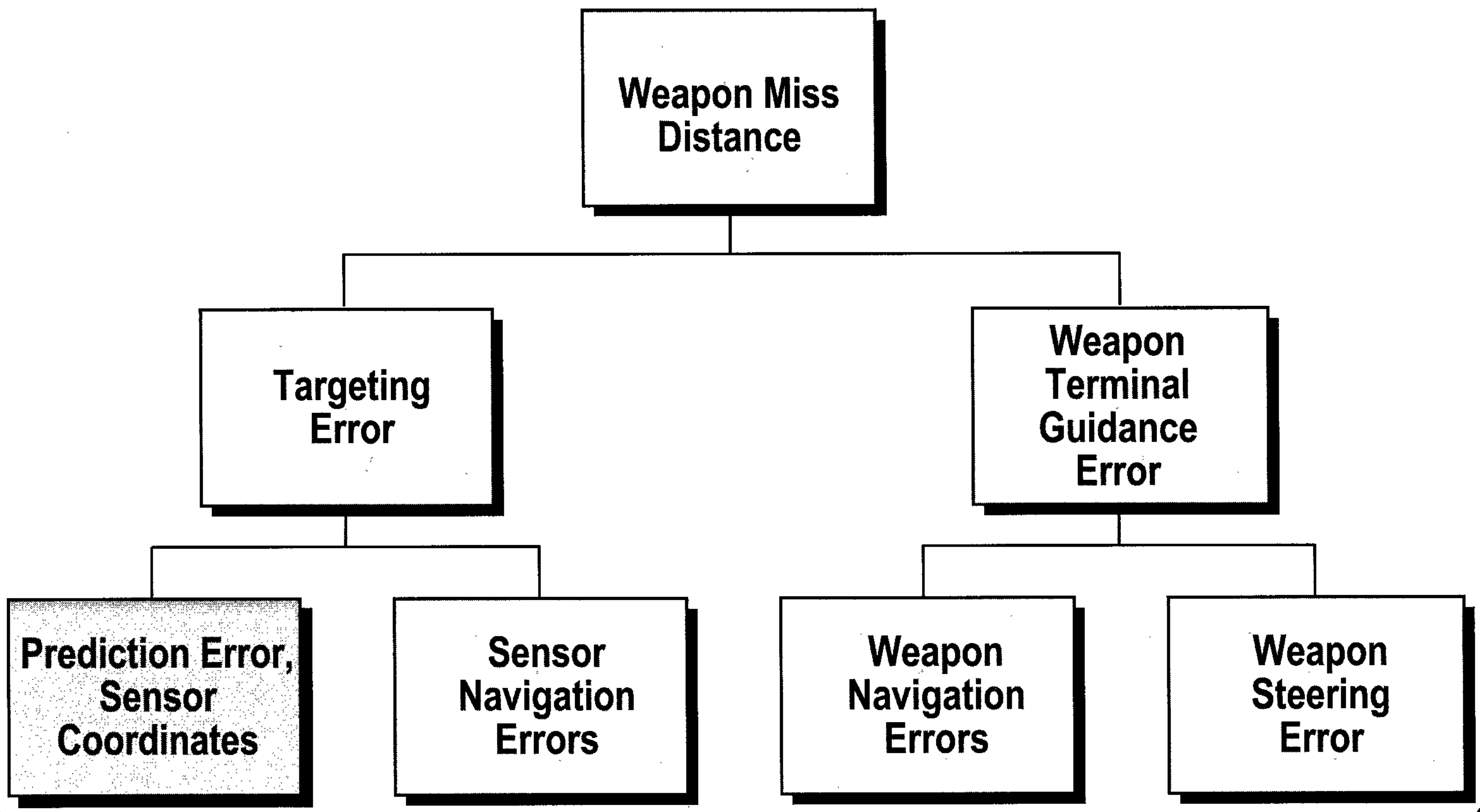
AMSTE Features

- Moving land and sea targets
- Reduced cost weapons
- Shooter survivability
- Targeting selectivity and precision
- Reduced logistics
- Increased load-out

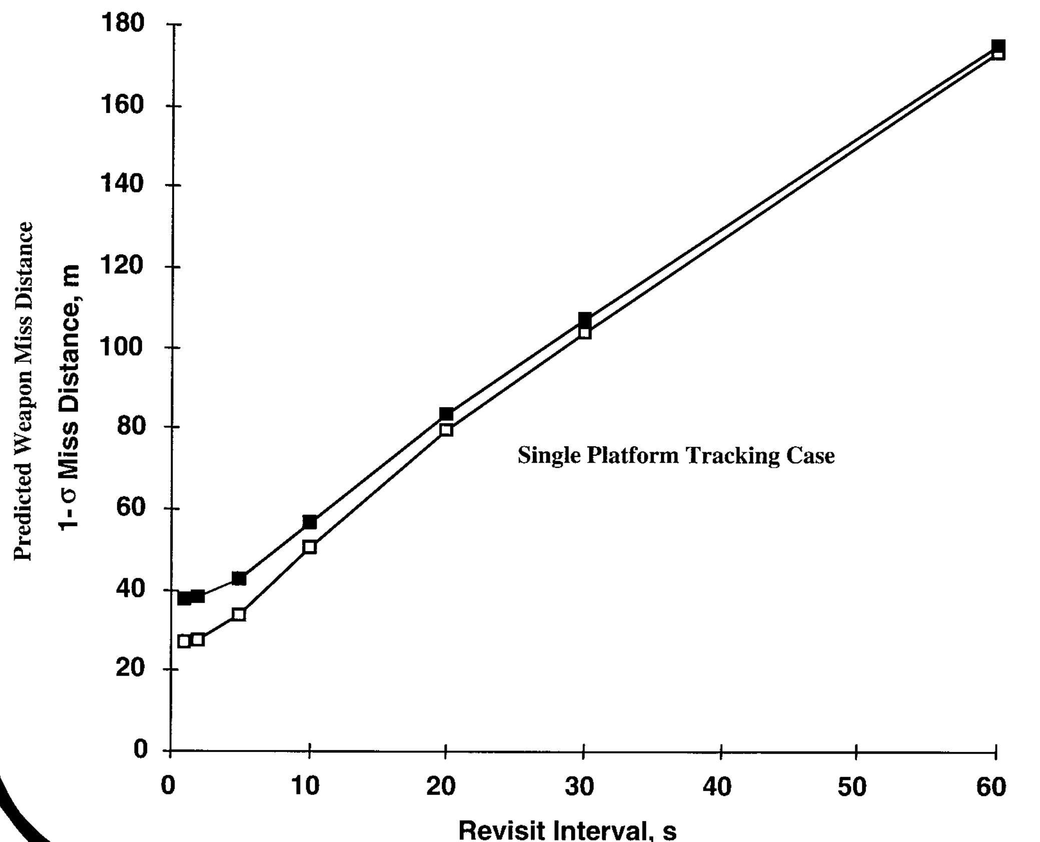
Feasibility Study

- Weapon miss-distance analysis
- Event-level simulation
  - High-fidelity vehicle movement
  - GMTI sensor/platform simulation
  - Laboratory GMTI tracker emulation
  - High-fidelity weapon simulation
- Error-source analyses

Error Sources



Track Prediction



Single Sensor

100 m 1σ Position Measurement Error

15 m/s Target Speed

Speed Variation
- 2.5 m/s speed variation
- 5 s correlation time

Nav Errors
- 6.6 m horizontal
- 13.8 m vertical

DTED Error
- 20 m vertical

Steering Error
- 1 m

Impact Angle
- 45°

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Targeting Accuracy

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ERROR SOURCE	CURRENT ERROR	FUTURE ERROR
TRACK PREDICTION	178 m	7 m
DTED VERT.	20	3
SENSOR HOR. NAV.	14	5
WEAPON VERT. NAV.	7	3
WEAPON HOR. NAV.	7	3
WEAPON STEERING	1	1
RSS MISS DISTANCE	180 m	10 m

Study Conclusions

- AMSTE is feasible
- Precision tracking is key
  - Multi-platform data needed
- Weapon system studies needed
  - Cost-performance trade space
  - Identify technical risks

AMSTE Program

Objective: Develop and demonstrate technology for affordable precision engagement against moving surface targets

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Program Structure SPO

Phase I:
Concept
Development

BAA

Phase II:
Fire Control
Experiments

Phase III:
Weapon
System
Experiments

Phase I: Approach

- Conduct weapons-system studies
  - Assess feasibility/cost
- Develop and evaluate fire-control precision tracking algorithms
  - Collect multi-platform data
- Investigate critical supporting targeting technologies

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Phase I: Products

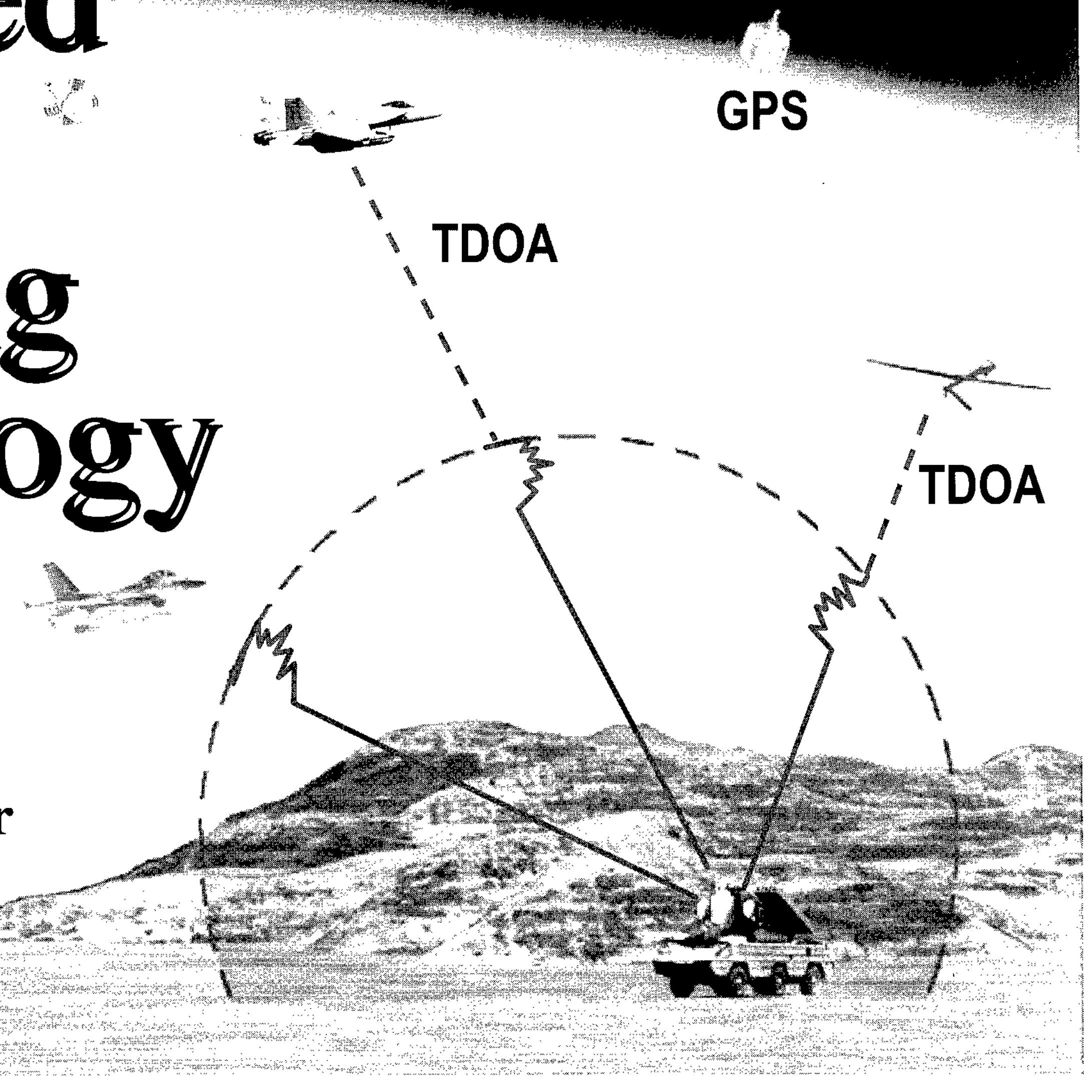
SPO

- Weapon system trade study
  - Feasibility/affordability assessment
  - Recommend follow-on experiments
- Precision fire control tracking
  - Develop and evaluate *government-owned* algorithms
- Multiple platform GMTI data

Summary

- Affordable moving target engagement is a critically needed capability
- DARPA's AMSTE program is developing and demonstrating technologies to support the *affordable* engagement of surface moving targets

Advanced Tactical Targeting Technology (AT3)



Lt Col Beth M. Kaspar
DARPA / SPO
bkaspar@darpa.mil
(703) 248-1520

Importance

- Surface-to-Air Threat Proliferation, Sophistication, and Mobility Is a Significant Threat to US Air Power
- Destruction of Mobile Air Defense Units is the Central Issue

- Accuracy / Timeline Sufficient for PGM Weapon Delivery

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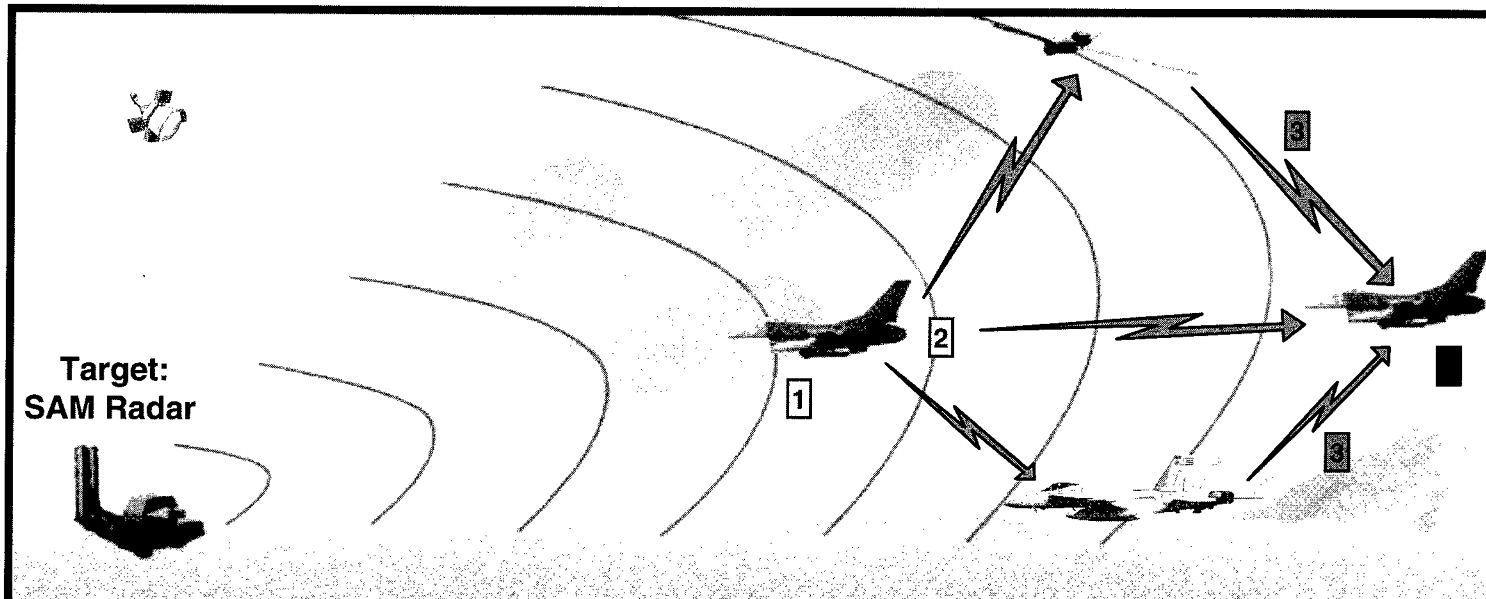
AT3

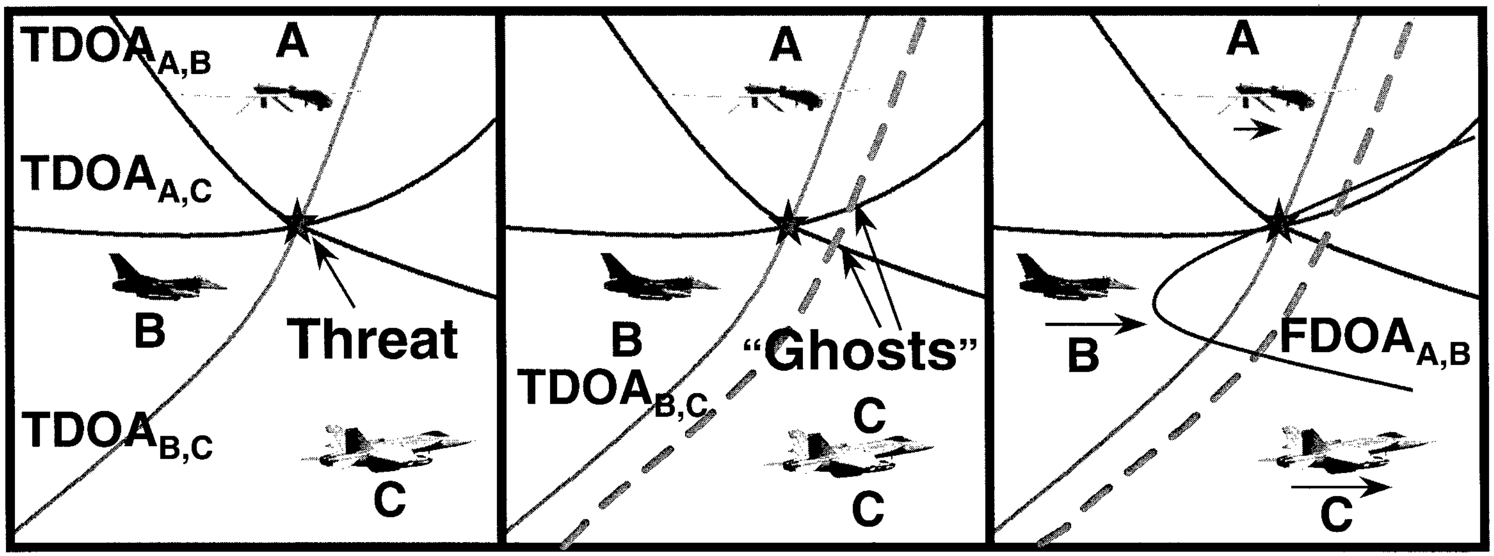
Develop and Demonstrate Enabling Technologies for A Cost Effective Tactical Targeting System for Lethal Suppression of Enemy Air Defenses (SEAD)

Targeting Concept



1 Detect, Classify, Select Target → 2 Broadcast Request → 3 Platforms Tune, Detect Target; Relay → Measures TDOA/ FDOA, Locate Target

Location

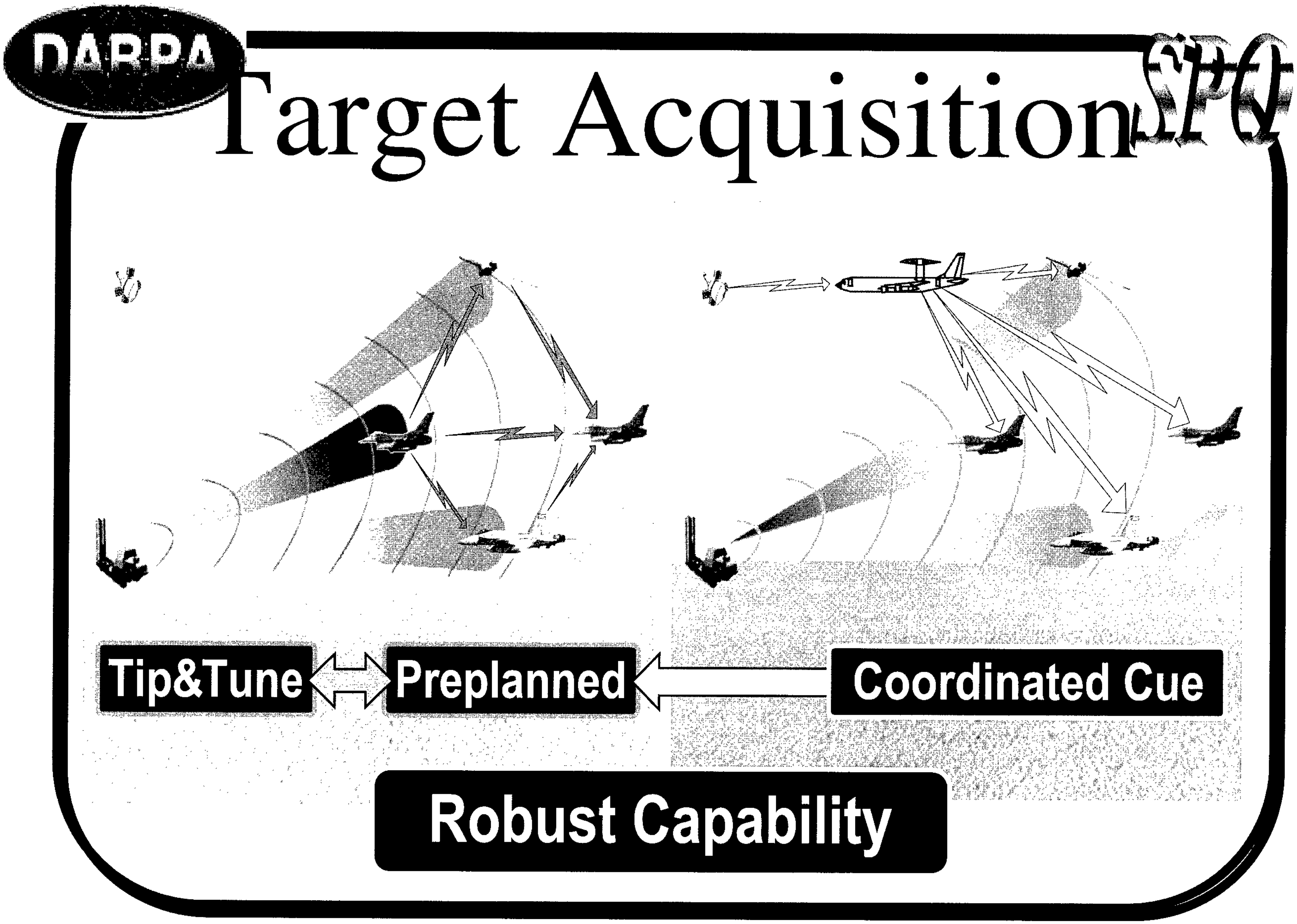


TDOA

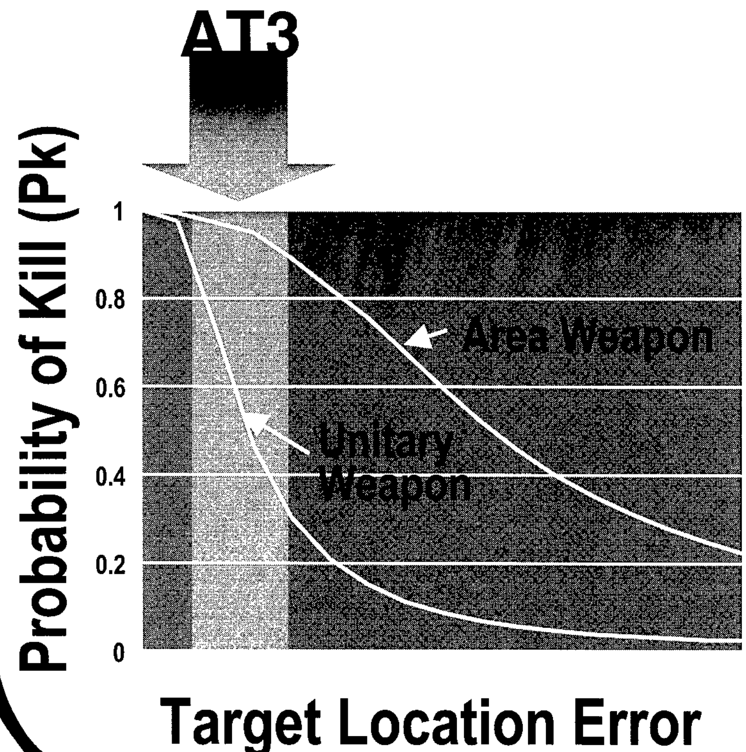
Ambiguities

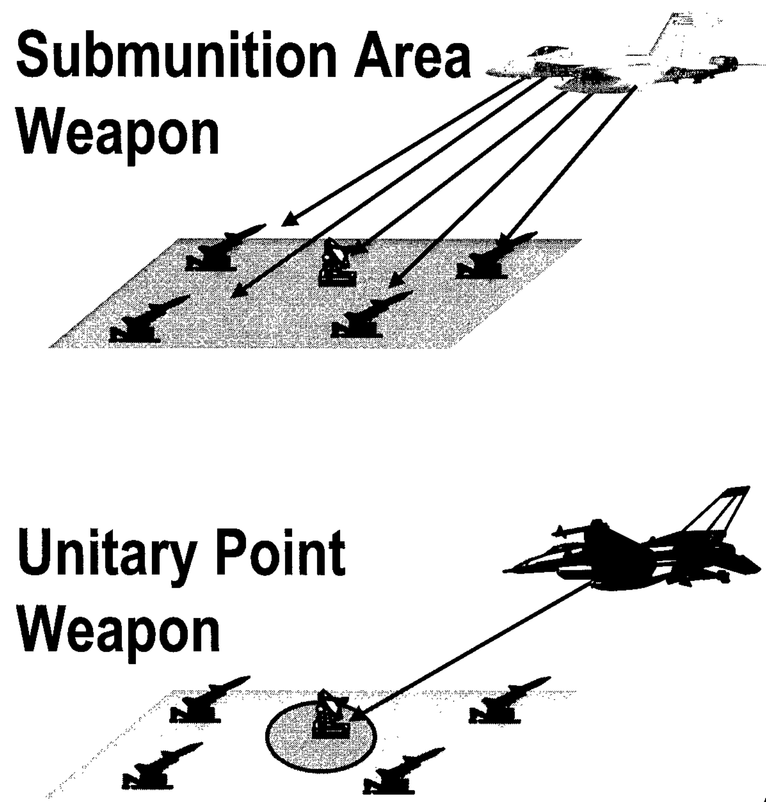
TDOA
& FDOA

Target Acquisition

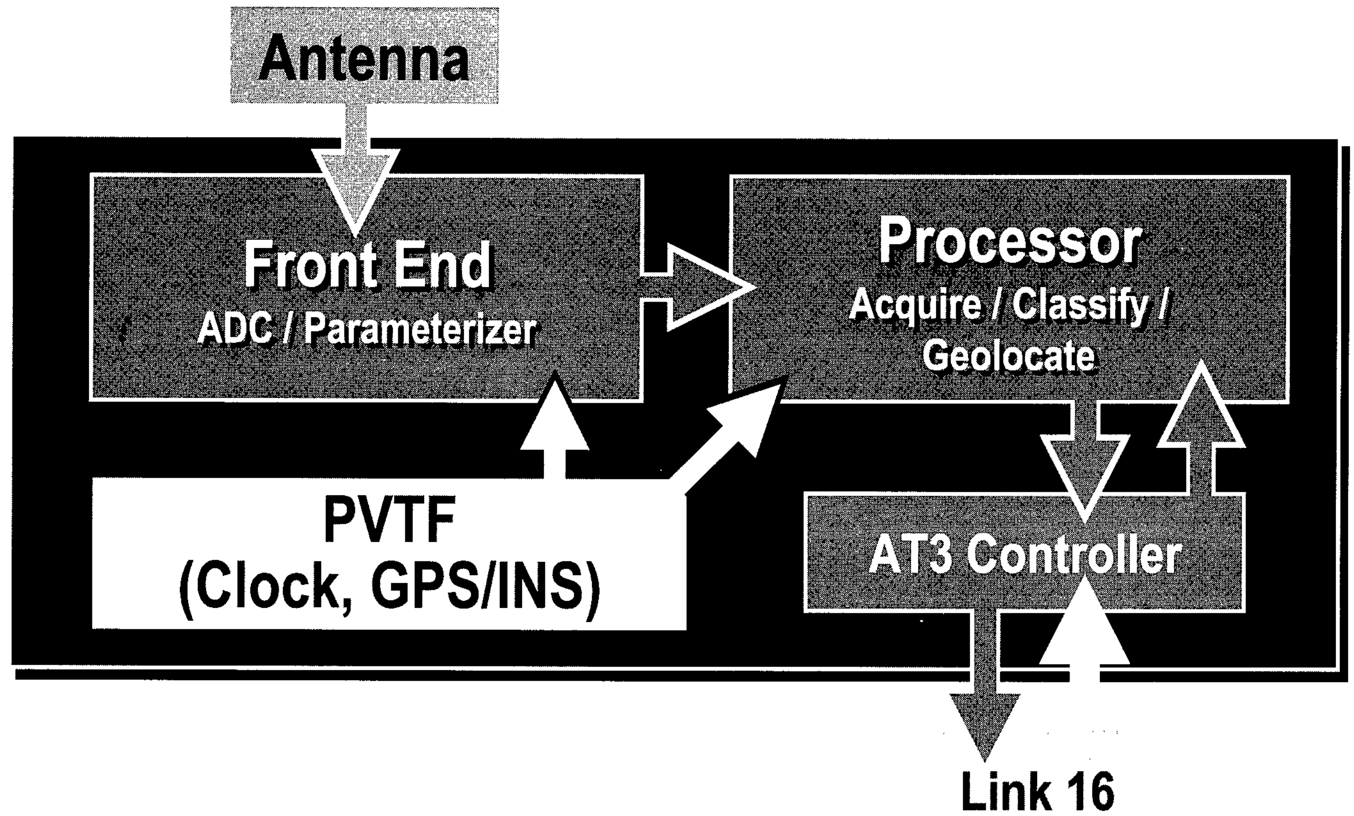


AT3 Uniqueness: TLE





AT3 Receiver



Challenges

- **Common Pulse:** Space / Time / Freq Alignment & Pulse Correlation
- **Threat Sidelobes:** Digital Receiver
- **Network Management:** Link 16 Access Control & Data Compression
- **Multipath Resilience**
- **Geolocation Algorithms**

Common Pulse

Collector A
- Detect
- Deinterleave
- Classify

Collector B
- Detect
- Deinterleave
- Classify

Collector C
- Detect
- Deinterleave
- Classify

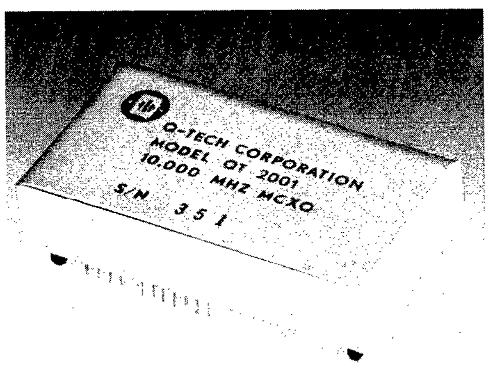
- Pulse Train Match
- Pulse Match
- CAF or FFT Processing
- TDOA/FDOA Measurement

Geolocation

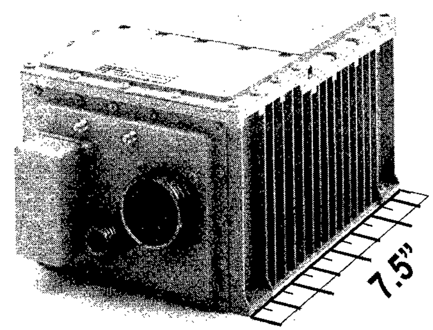
7D Registration

Commonly Registered 3 meter, 0.03 m/sec, 5 nano-sec P-V-T

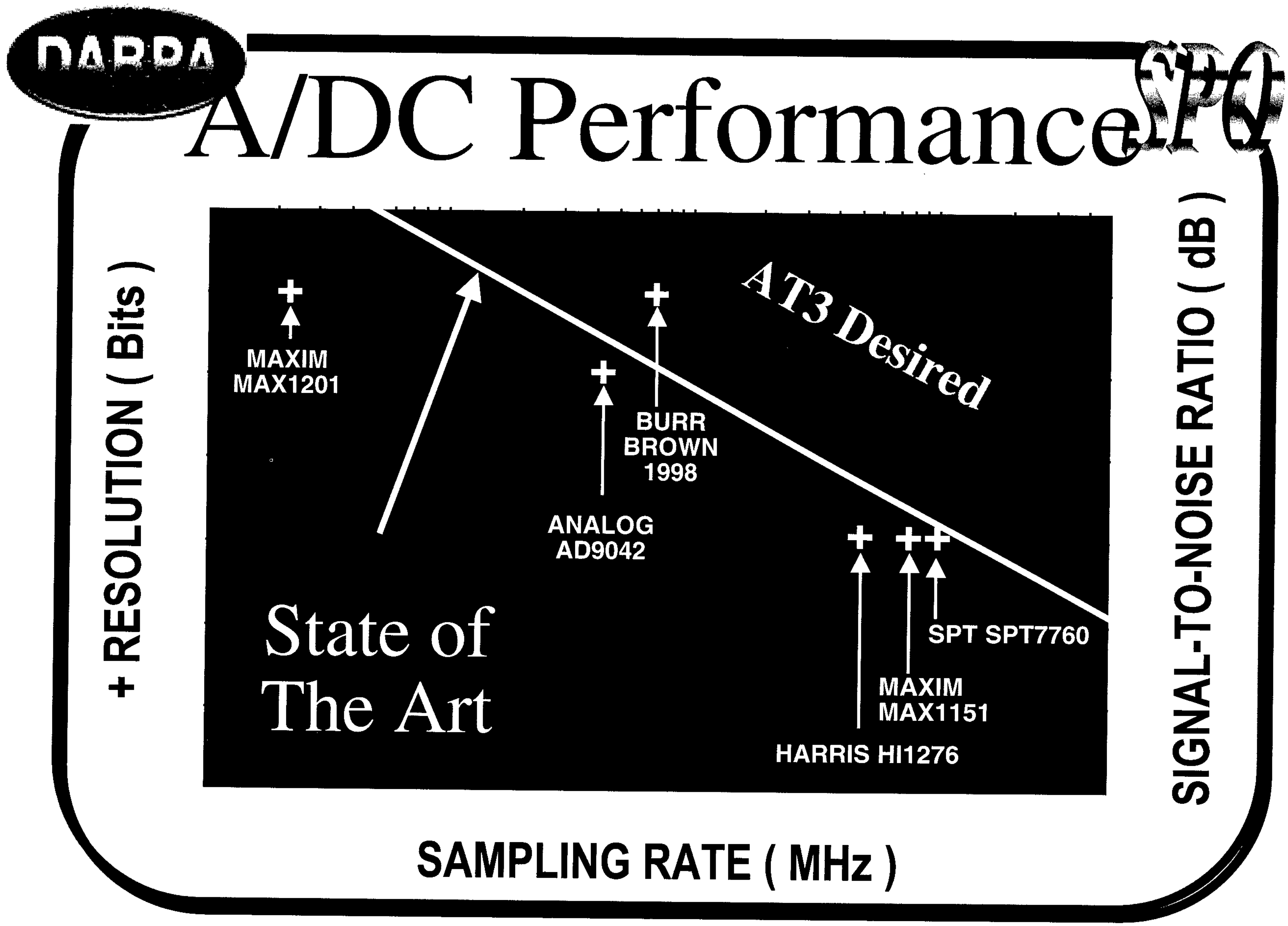
Miniaturized Precision Clocks



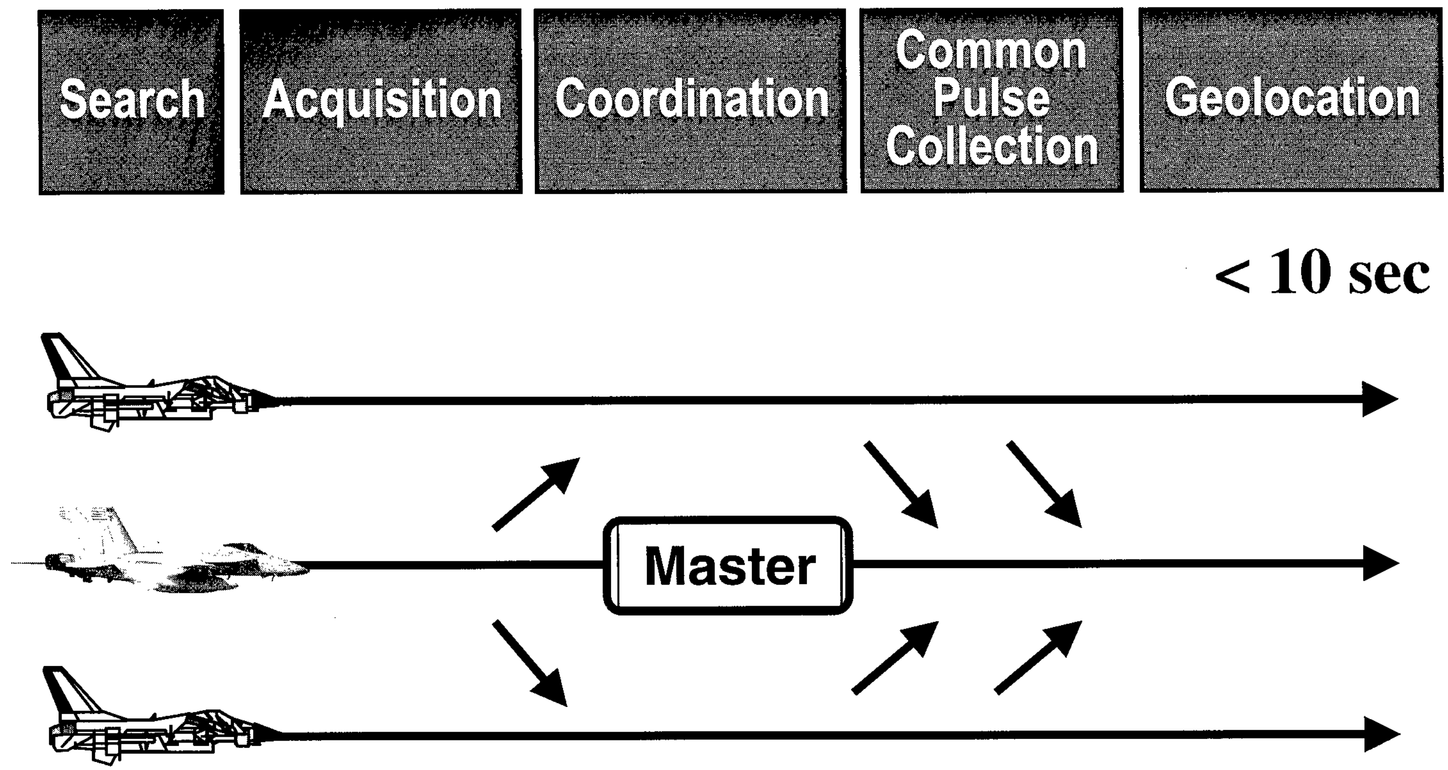
GPS Guidance Package



A/DC Performance



AT3 Timeline



Link Management

Net 1

Net 2

Net 3

Request	Own Nav State LSB	Target Characterization: Type, RF, SNR, etc.	TOA MSB	Sampled Waveform

Net 4

Sampled Pulse 1 — Sampled Pulse 2

TOA1 LSB — TOA2 LSB — (etc.)

Data Compression

- Match Data Link
- > 3:1 for Sending Sampled Pulses for Coherent Processing
  - Wavelets
- Pulse Descriptor Words for Non-Coherent Processing

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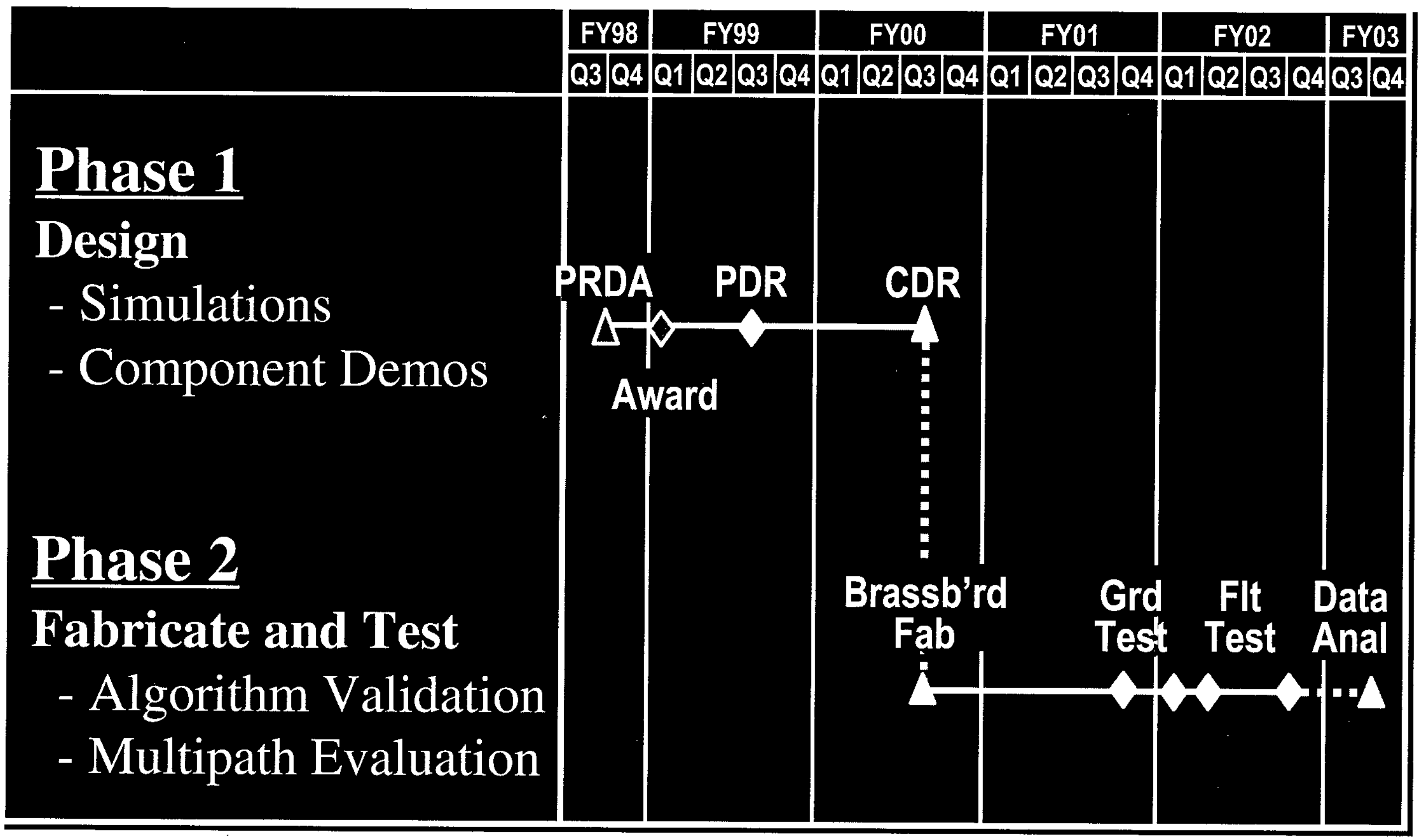
Schedule



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Opportunities

- Advanced Geolocation Algorithms / Technology
- Multipath / DTED Exploitation / Geometry
- Reconfigurable Digital Receiver

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PRO-Active Computing

- Get **P**hysical
- Get **R**eal
- Get **O**ut

Dr. David Tennenhouse, Director
Information Technology Office

ITO

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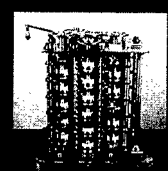
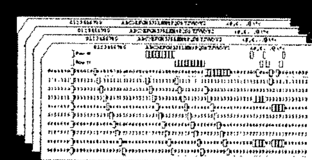
PRO-Active

A Brief History of Information Technology

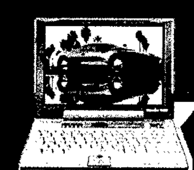
Numeric Computation

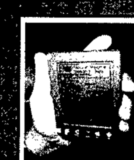


Symbolic Processing



Interactive Computing





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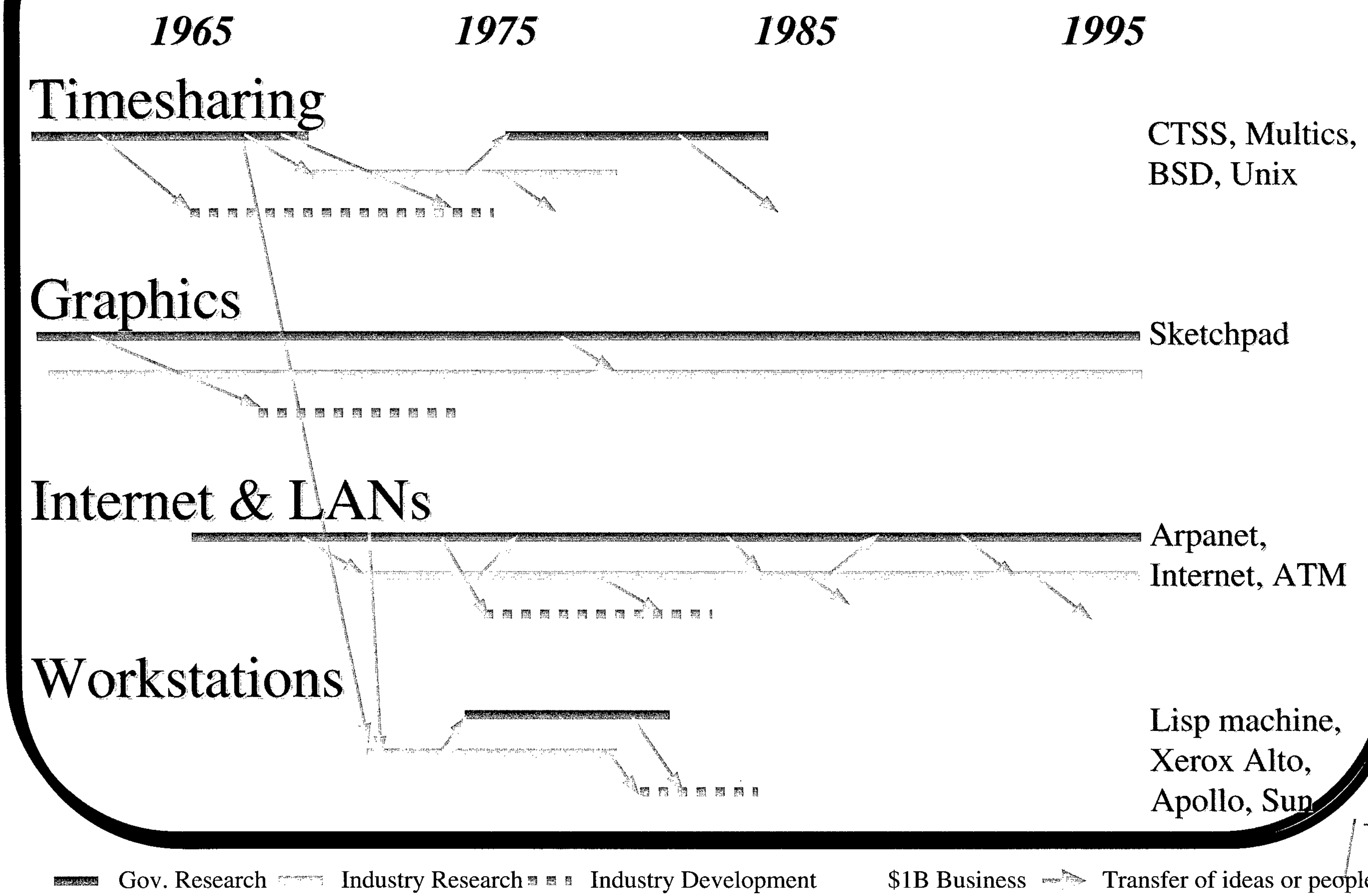
Success Stories



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A Brief History of DARPA I.T.

Interactive Computing

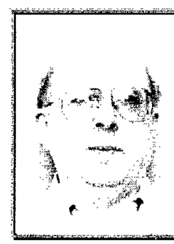
1962- present (J. Licklider, B. Taylor, I. Sutherland)

Strategic Computing

1974- present (Bob Kahn)

Artificial Intelligence

(Saul Amarel)



High Perform. Computing

(Steve Squires)

1960's ***1970's*** ***1980's*** ***1990's***

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DoD Impact

Interactive Computing →	Command & Control
Strategic Computing →	C4ISR
High Performance Computing →	DOE, NSA, NRO, etc.

DARPA

PRO-Active

Beyond Interactive Computing…

Lets “Declare Victory” on Command & Control!

- Get Physical
- Get Real
- Get Out

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PRO-Active Computing

"Declare Victory" on White Collar Computing

- Why?
- Why Now?
- How?

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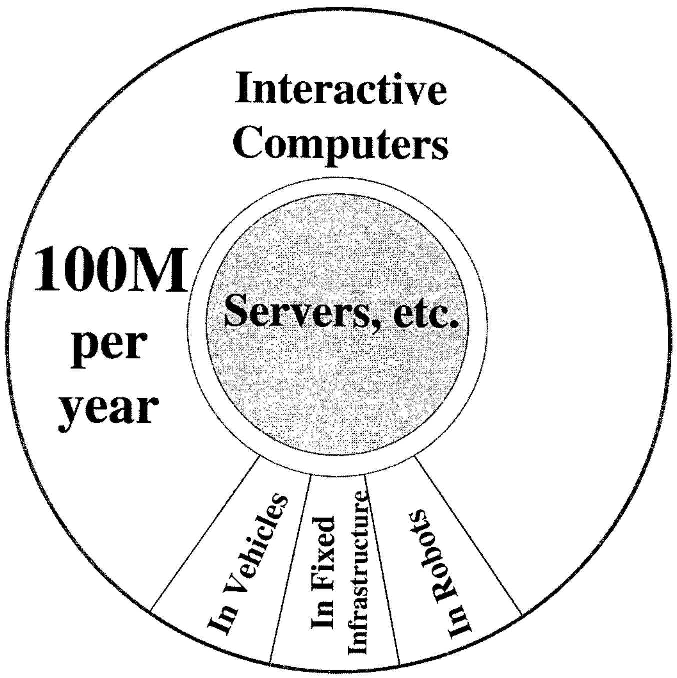
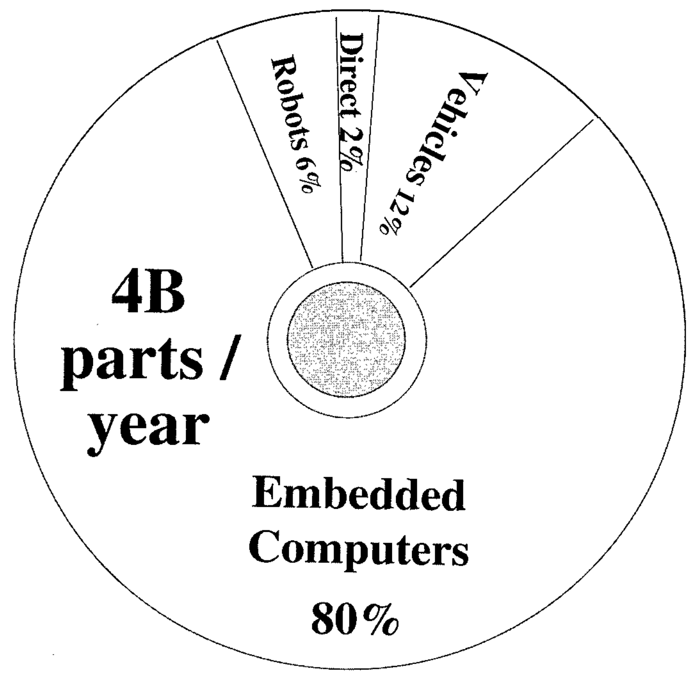
Where Will the Computers Be?

Where Has CS Focused?



Where Are The Processors?



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Projected CPU Shipments In 2000

Micro-controller Solutions
8,288,300,000

Cores ???	MCU's 7,257,000,000	Embedded MPU's 281,300,000	DSP 600,000,000	Computational MPU's 150,000,000
16 bit (ARM)	4 bit 1,680,000,000	8 bit 20,200,000	TI	x86
32 bit (MIPS)	8 bit 4,770,000,000	16 bit 108,000,000	AMD	PowerPC
ASSP	16 bit 764,000,000	32 bit 153,100,000		SPARC
ASIC	32 bit 43,000,000			

Source: Data Quest plus additional information

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Why Now?

Inflection Points

- ***Reinvention*** of embedded processors
- ***Deep Networking*** of the missing 98%
- ***Limits*** of interactive computing

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DARPA

PRO Active

Isn't This The Same As Ubiquitous Computing?

- Human productivity is common objective
- However, ubiquitous computing remains centered on
  - Human-in-the-loop paradigm
  - White-collar applications

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How Do We Move Forward?

- Where are the opportunities?
  - –Getting Physical
  - –Getting Real
  - –Getting Out

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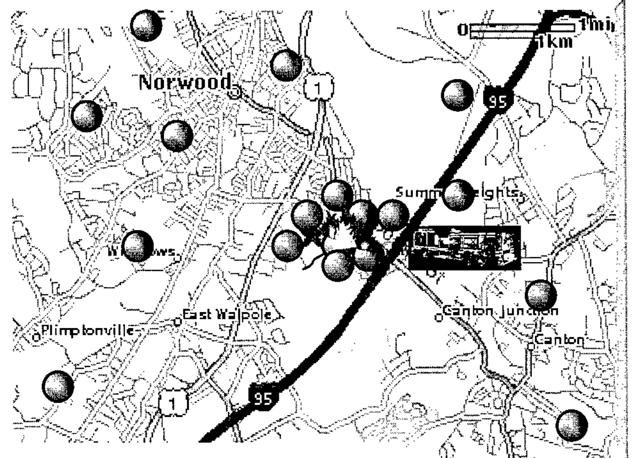
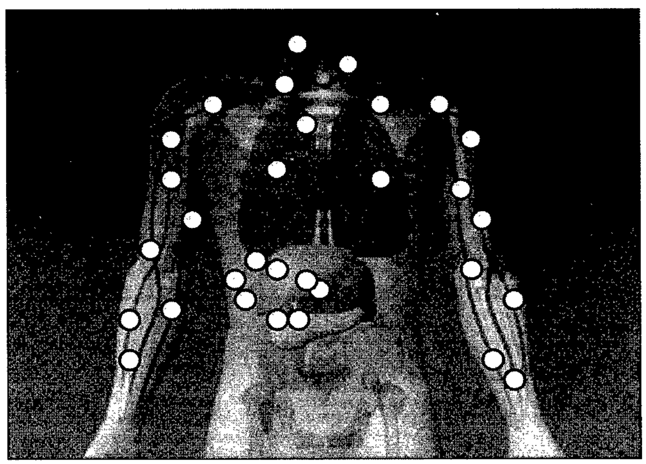
Get Physical

Attain pervasive physical locality to subjects of interest





Direct coupling to the physical world via networked devices

Targets: Vehicles, Infrastructure, Factories, Human Body

DARPA

Get Physical

PRO-Active

Bridge the Physical and Virtual Worlds

- Sample Challenges / Opportunities
  - Virtual Radios
  - Software-Enabled Control
  - National Scale Instrumentation
  - Sensor Information Technology

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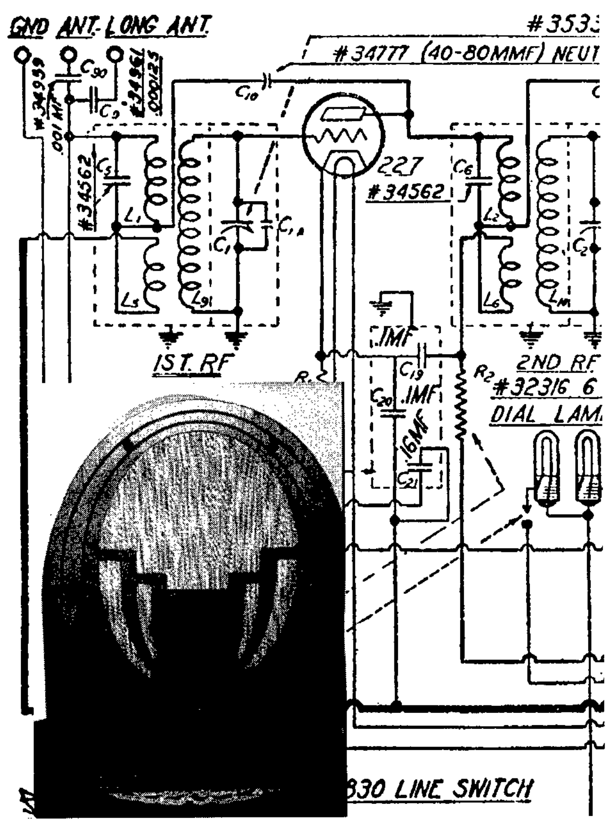
Getting Physical

Virtual Radios

Edison's Radio

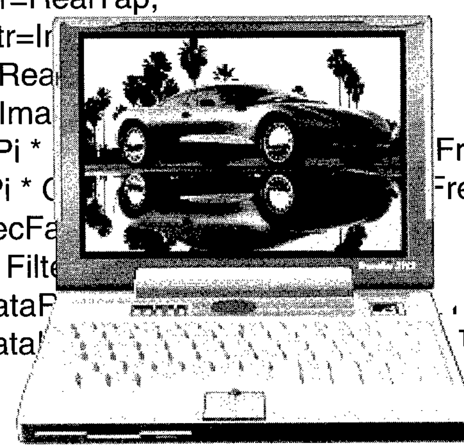


Turing's Radio

```
pages = (BlockSize/4096) +1;
if((guppi_open("guppi0",pages)) < 0 )
  exit(0);
guppi_start_rec();
for ( i=0 ; i< NumBlocks ; i++){

  pdata = (char *)guppi_rec_buf();
  for ( j=0 ; j< IntsPerBlock ; j++){

    RealTap_ptr=RealTap;
    ImagTap_ptr=Ir
    OutputDataRea
    OutputDataIma
    a=cos(TwoPi *                    FreqIn * index);
    b=sin(TwoPi * C                  FreqIn * index);
    index += DecFa
   for ( k=0; k< Filte
      OutputDataF                    ap[k]);
      OutputData                     Tap[k]);
...
```



Disclaimer: "This is not an approved DARPA program. This alternative is under consideration."

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Software-Enabled Control

Getting Physical

Translate

Ht(x)=..............
Hd (x)=
Hk (x)=
Hc (x)=

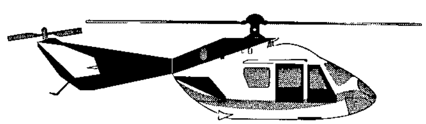
Ascend

$H_t(x)=$..............
$H_d(x)=$
$H_k(x)=$
$H_c(x)=$

Descend

$H_t(x)=$..............
$H_d(x)=$
$H_k(x)=$
$H_c(x)=$

Hover



$H_t(x)=$...............
$H_d(x)=$
$H_k(x)=$
$H_c(x)=$

?

```
if ((veloc < 2.0) & (accel <
  0.05) & (alt > 5.0)) then
   transitionmode(forward,
     hover,veloc,accel,alt)
elseif (accel > 1) {
   -----------------
}...
```

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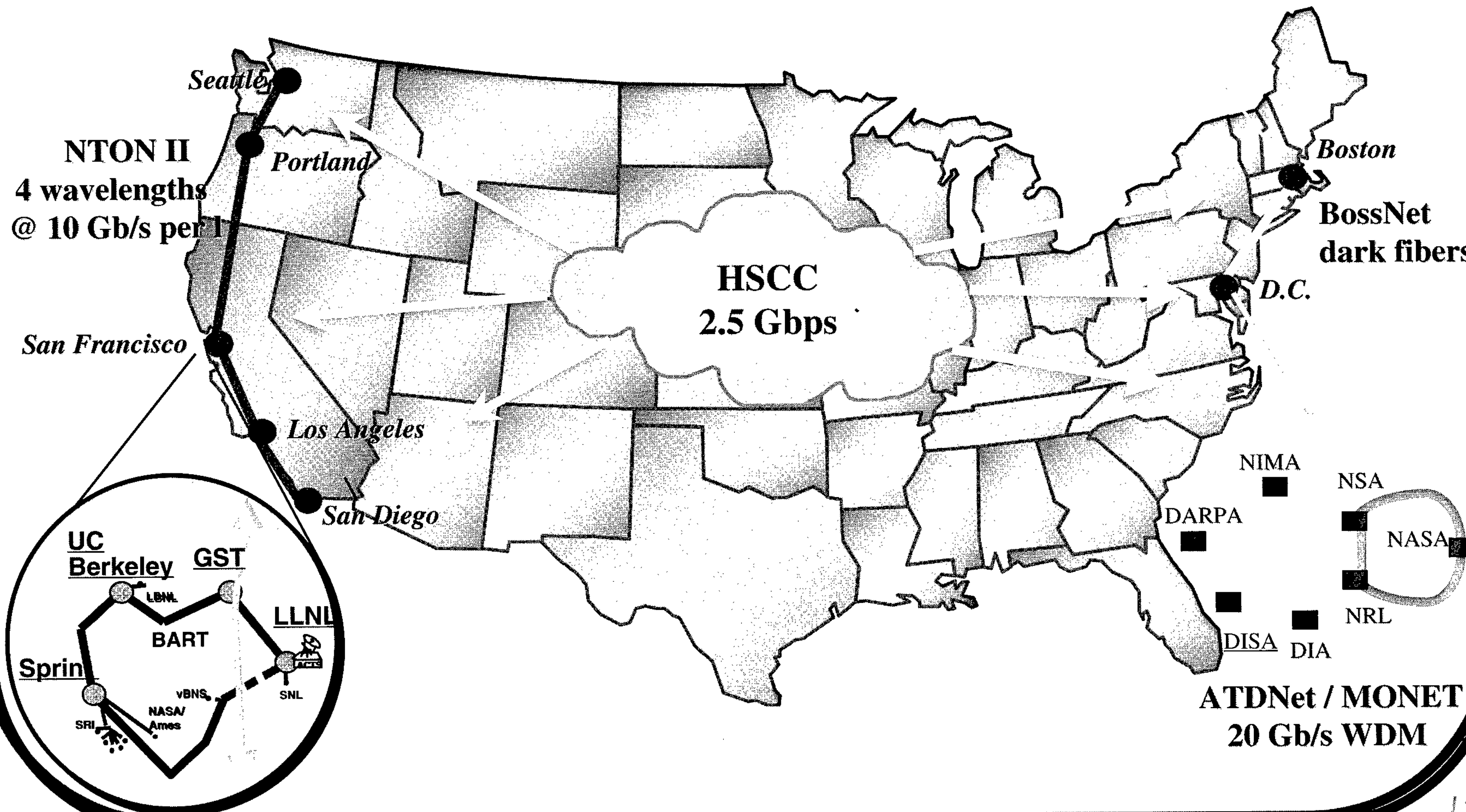
National Scale Instrumentation

Getting Physical



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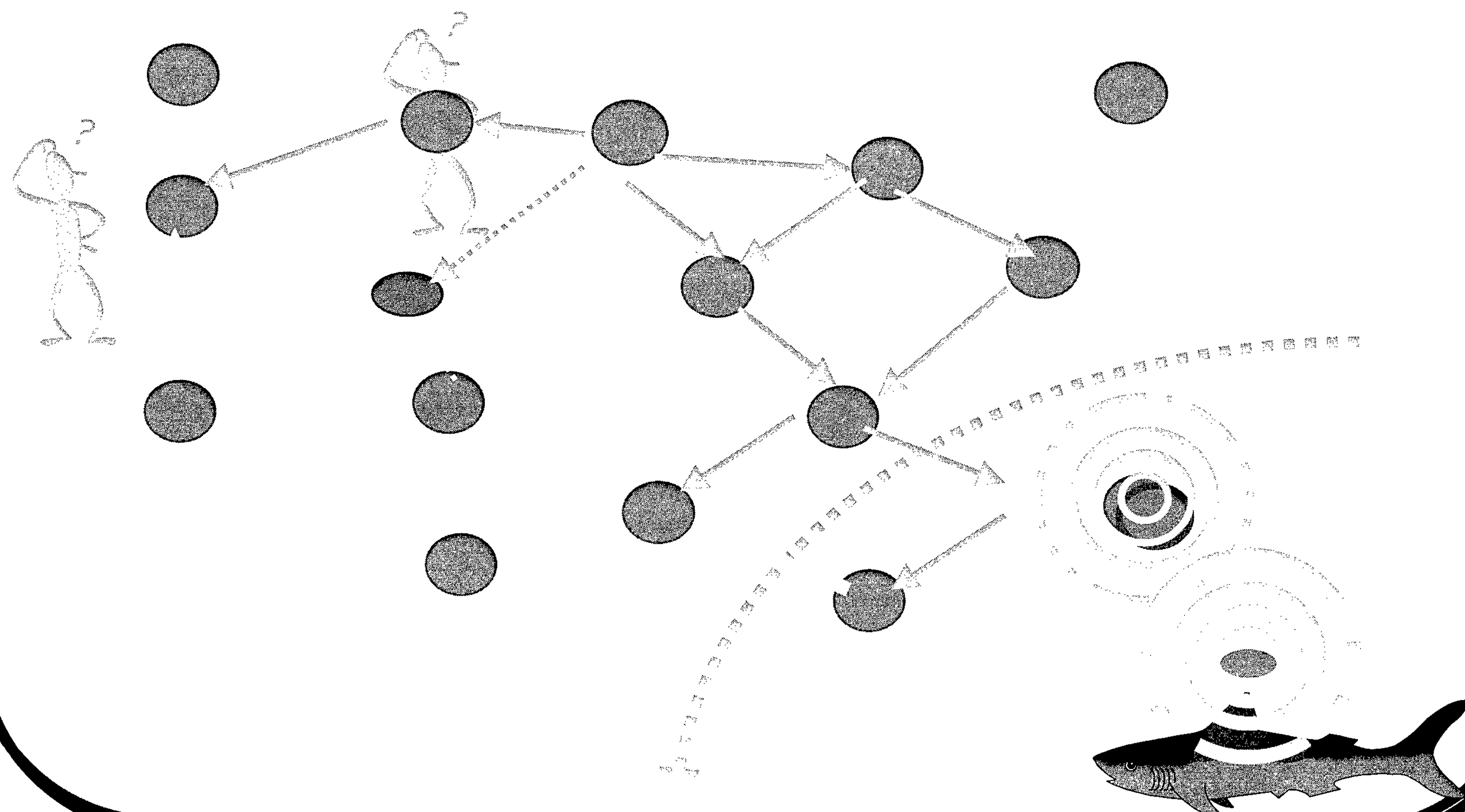
Getting Physical

Sensor Information Technology



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Getting Physical

First-Class Software for Embedded Systems

- Software to bridge the gap between single nodes and useful systems is missing …
  - How do you enable "multi-tasking" of large collections of embedded nodes?
  - How do you "query" a sensor network?

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Let's Get Real

Operate at Faster-Than-Human (>10hz) Frequencies

- Drive applications towards real-time.
- Squeeze latency out of every system
- Enable fine-grained, high frequency interaction across subsystems.

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Getting Real

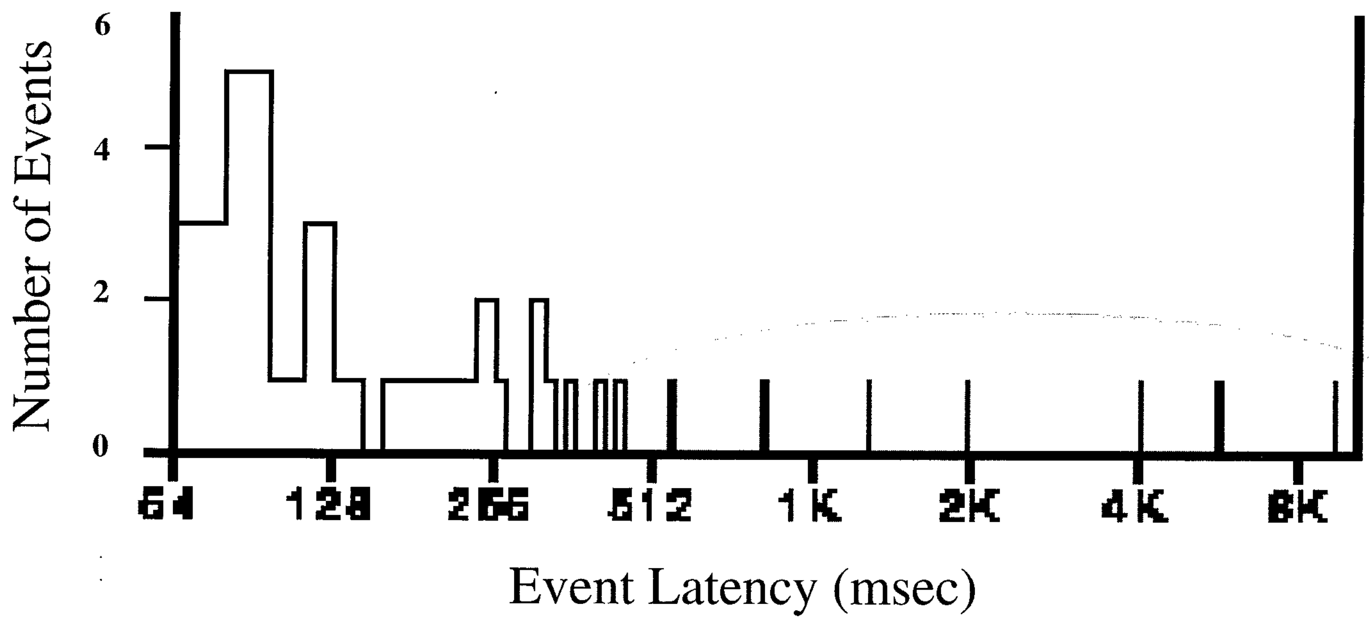
- Sample Challenges / Opportunities
  - Quorum Operating System
  - Faster-Than-Real-Time Simulation
  - Just-In-Time Hardware
  - PRO-Active Biology

Getting Real

Quorum Enhancements to NT

Distribution of Event Latencies on NT 4.0

(Endo, et al, 1996)



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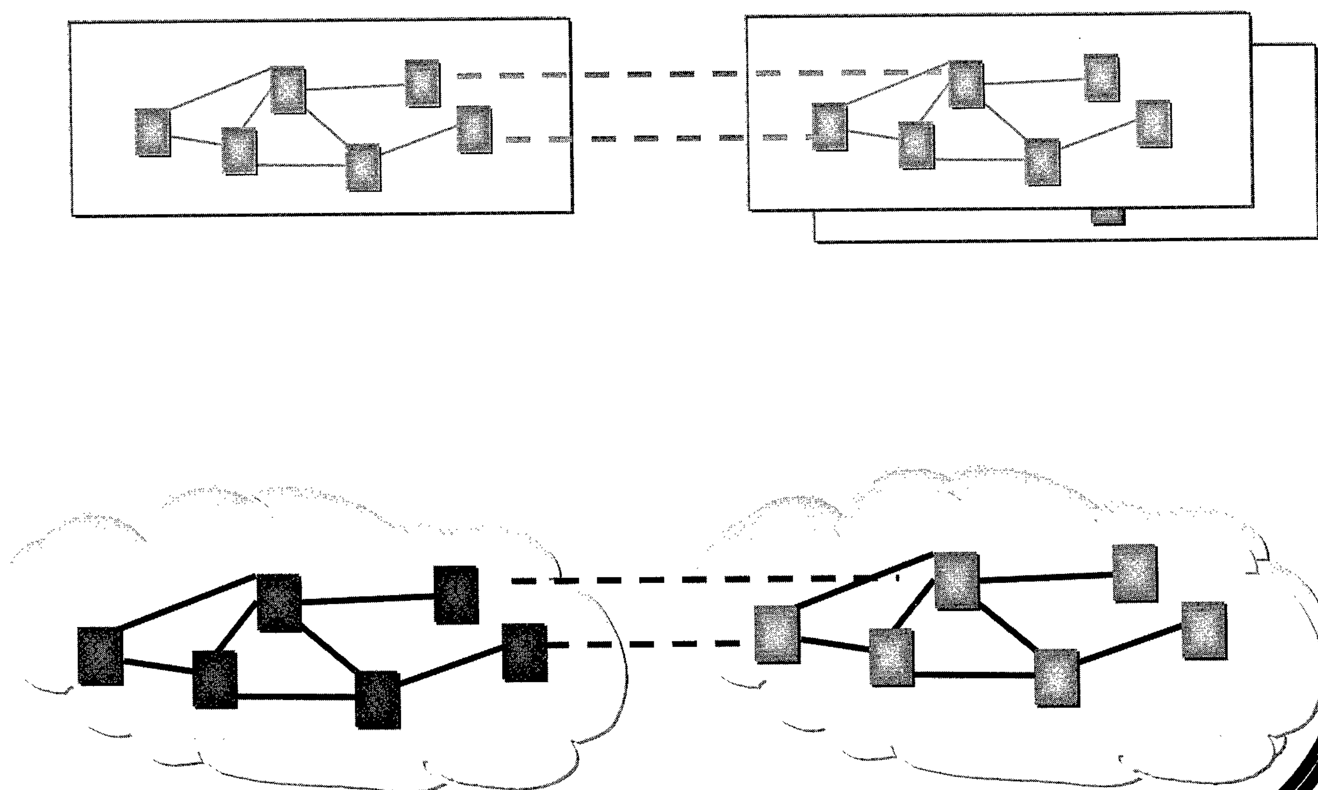
Getting Real

Faster-Than-Real-Time Network Simulations

simulators

real world networks



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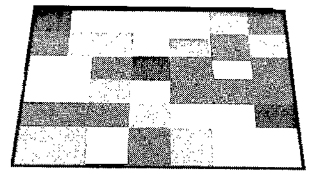
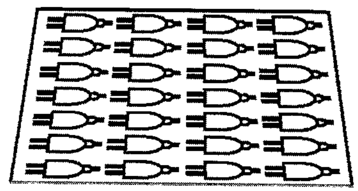
Getting Real

Just-in-Time Hardware

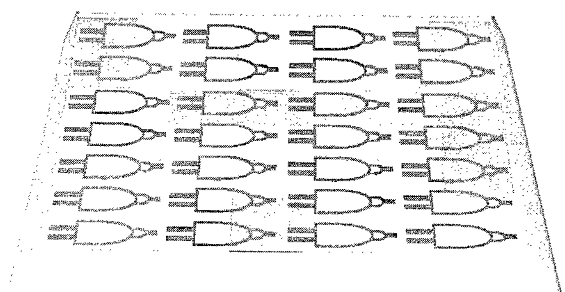
Application



Sea of Gates



Instantly "Wired"



Run-Time Configurable Computer

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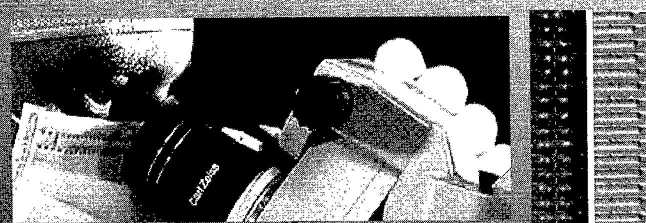
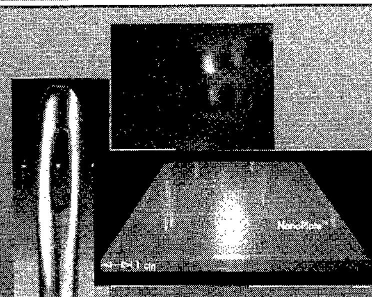
PRO-Active Biology

Getting Physical

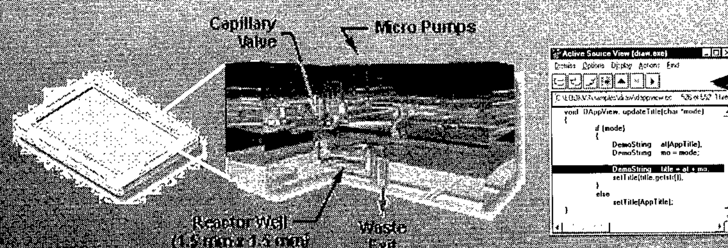
Real-Time Monitoring



Lab-on-a-Chip



Access to Experiments in Progress



Interactive Benchstation

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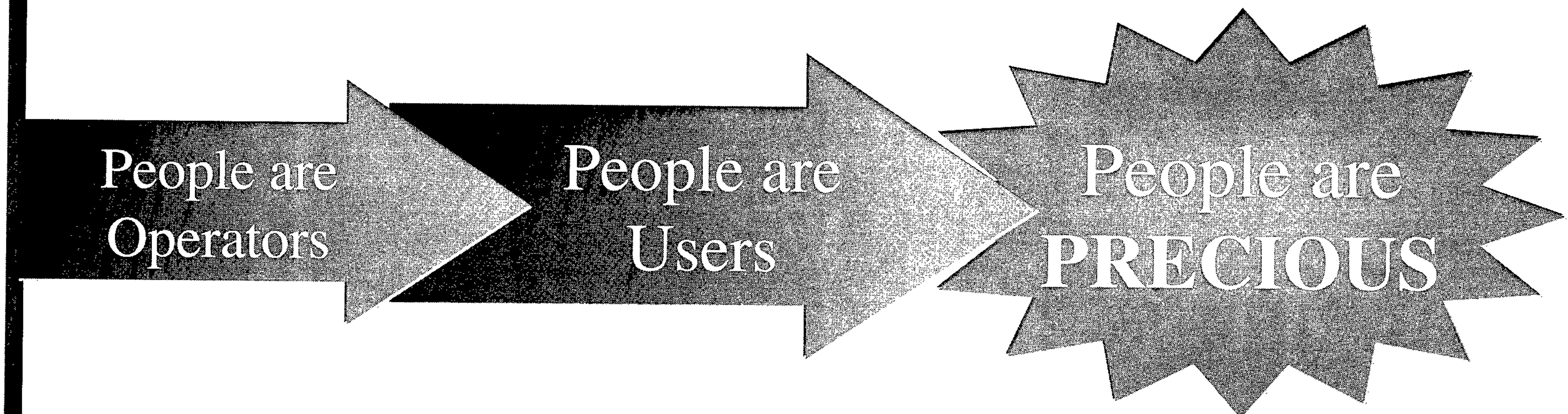
Getting Out



Get the Humans Out / Above the "Loop"

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Getting Out

PRO-Active

Get the Humans Out / Above the "Loop"

- Sample Challenges / Opportunities
  - First Class Software for Robotics
  - Distributed Agents / Knowbots
  - "Above the Loop" Approaches to HCI

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Getting Out

Robotics Research Without Building Robots(?)

Leverage the progress in mechatronics

<u>Goal</u>
Many robots / person

<u>State-of-the-Art</u>
One robot / person

Proposed Research

<u>State-of-the-Practice</u>
Several people / robot

Develop the <u>missing software</u>

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Teams Of Knowbots

- Leverage mobile code (agents) to achieve autonomous negotiation of large scale problems.
  - faster-than-human speed
  - millions of knowbots / person
  - allocation good enough & soon enough

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What About HCI?

Getting Out

- What Has Worked?
  - Interactive HCI Platform ≈ Computer
  - Single focal point / intermediary
- What about the PRO-active HCI?
  - How does a person direct thousands of devices? or millions of agents?

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Getting Active

PRO-Active

Java Is 5% of a Much Bigger Story ...

- Technical Challenges / Opportunities
  - Autonomous Knowbots
  - Active Networks
  - Active Software

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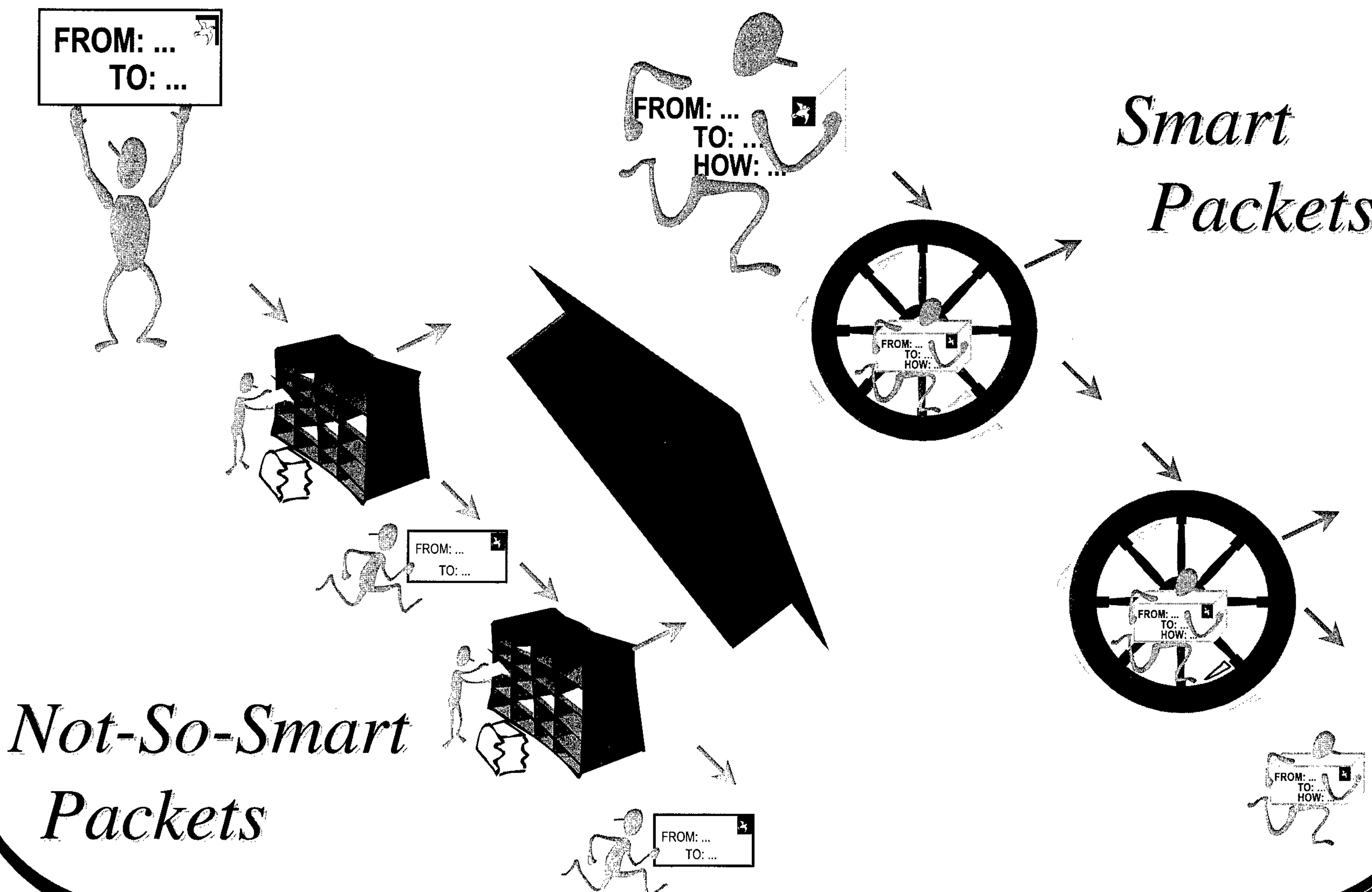
Active Networks



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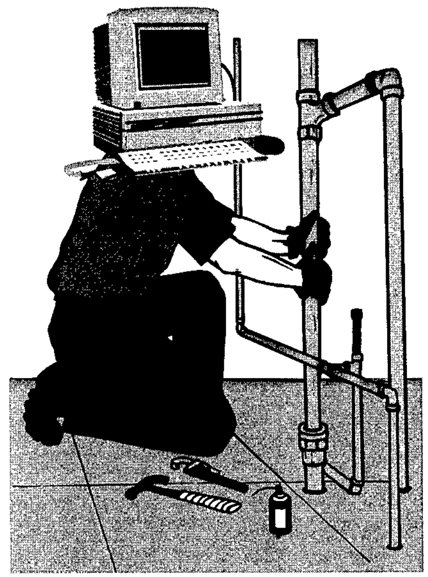
Active Software

Software That Reconfigures Itself *While Running*



How does code mobility change the way we think about software?

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Disclaimer: "This is not an approved DARPA program. This alternative is under consideration."

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Can We Get Physical / Real / Out / Safely?

- Yes…

  but that's another story.

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How Does PRO-Active Move DoD Forward?

- Protection from Biological Attack
- Dynamic Battlefield
- Affordable, Precision Target Engagement
- Mobile, Distributed C^3
- Combined Manned & Unmanned Warfare

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PRO-Active Computing: The Other 98%

- We have only addressed 2% of the CPUs!
- The other 98% are embedded
- How does the world change with:
  - 1,000 processors / person?
  - Too many to bother keeping track of?

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Software for Autonomous Systems

Mark L. Swinson, Ph.D., P.E.
Colonel, U.S. Army
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Program Vision

Develop the needed
Software Technologies
to enable the safe, reliable, and
cooperative operation of
autonomous, free ranging
systems for the real world

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Program Scope

- Software (only) systems - **Knowbots**
- Software-enabled, physically embodied, mobile systems - **Robots**

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Knowbot Themes

- Information Retrieval
- Information Delivery
- Information Generation (especially negotiation)

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Robot Themes

- New Capabilities
- Enhanced Capabilities
- Reduced Cost

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ITO Programs

- Knowbots
  - Autonomous Negotiating Targets
- Robots
  - Mobile Autonomous Robot Software
  - Software for Distributed Robotics
- Software Enabled Control

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ANTS Vision

- Autonomously negotiate the assignment and customization of resources to tasks
- Applications include logistics, electronic countermeasures, and reactive weapons control

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"You don't get what you deserve, you get what you negotiate."

Chester Karras

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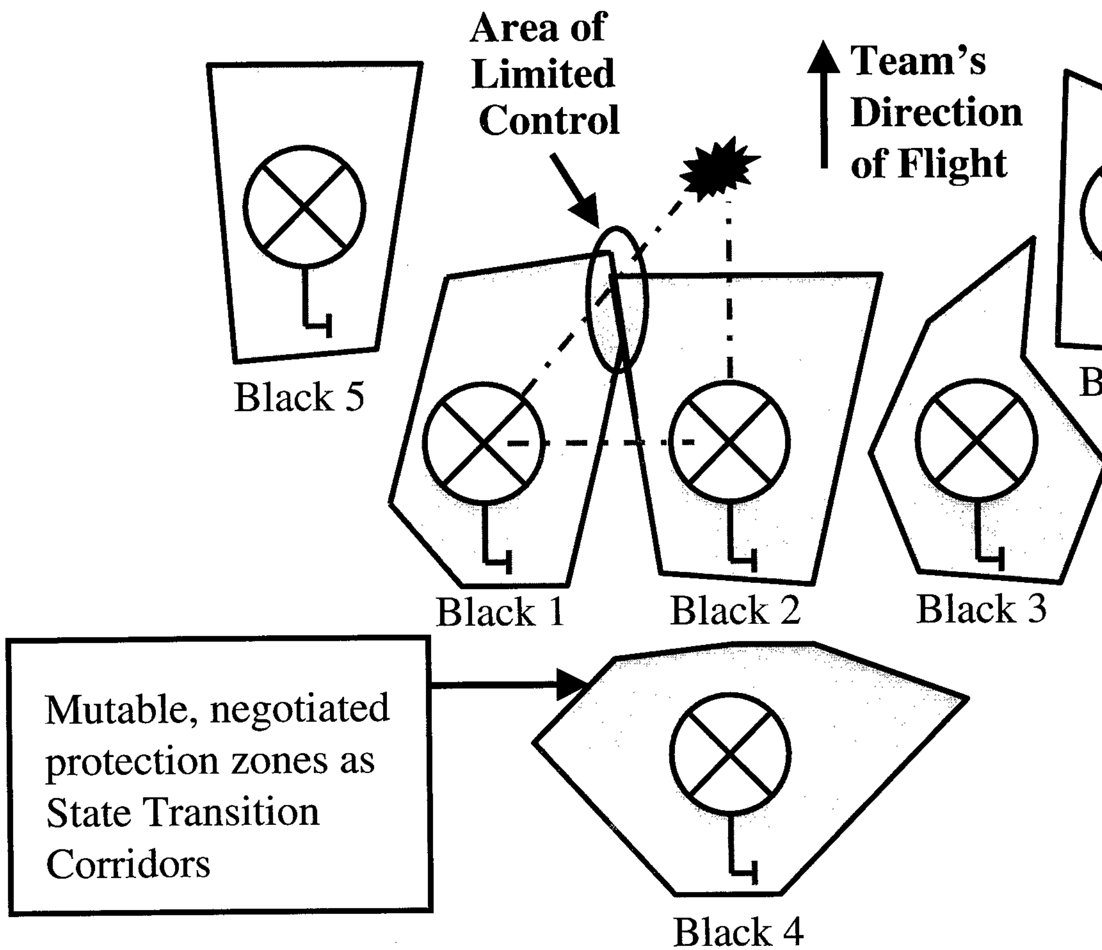
ANTs Technology Application



Could ANTs have prevented the 1996 Australian Army Blackhawk Collision?

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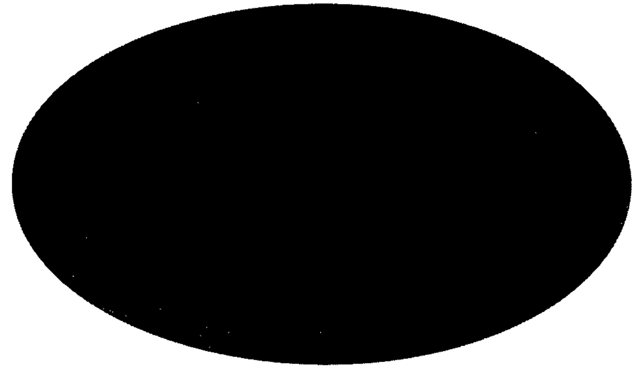
MARS Vision



MARS Research

State-of-the-Art

Telesupervised:
One robot/person
"tank commander"

State-of-the-Practice

Teleoperation:
Several people/robot
"tank driver"

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MARS Goals

- Enhance the autonomy of robot systems
- Enhance the utility, ease of development, and reusability of robot software

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Research Issues

- Predictability
- Robustness
- Data Structures
- Adaptability
- Software Composition

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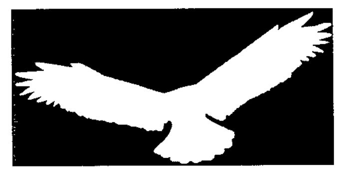
Software Approaches

- Pre-programmed
- Learning-derived

Soft Computing



Robot Shaping

Imitative Learning

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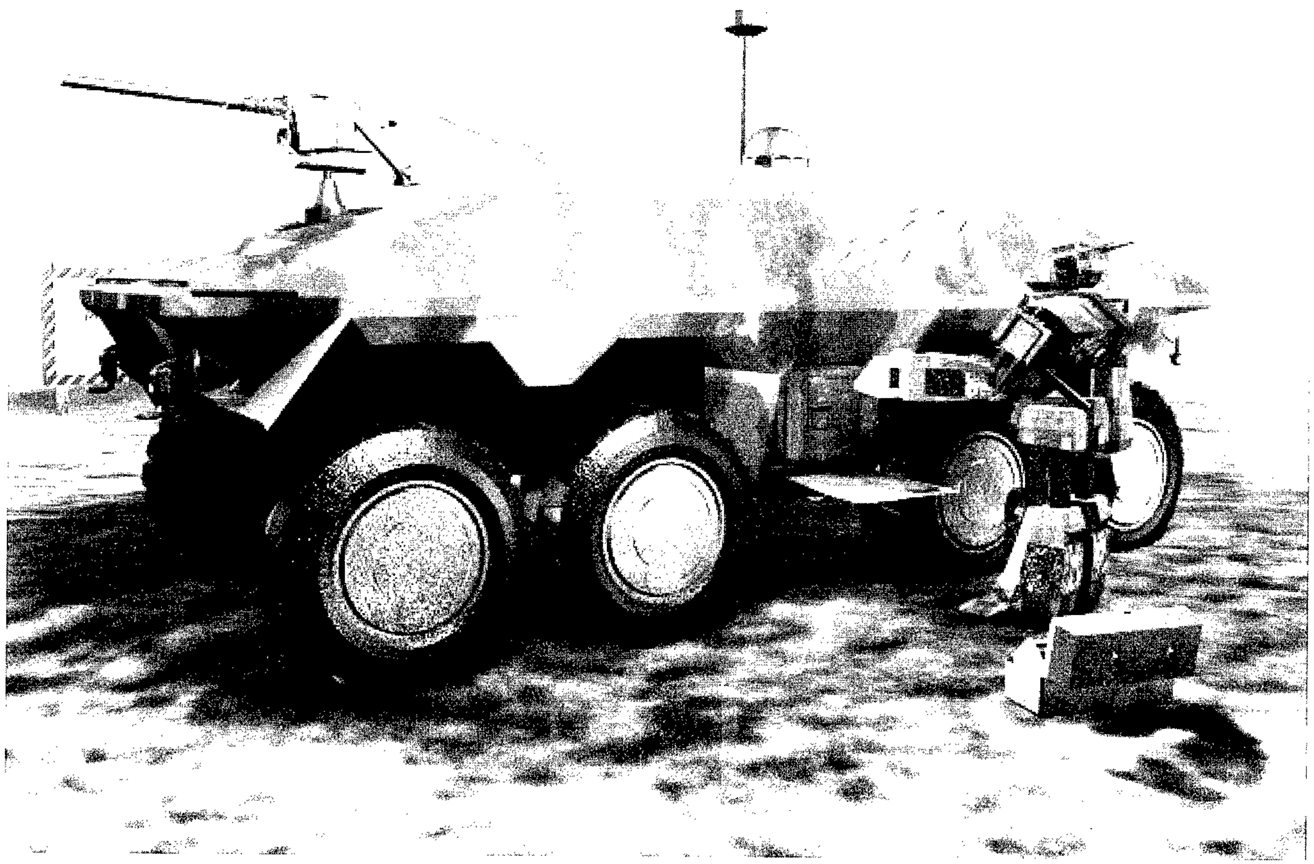
MARS Robots



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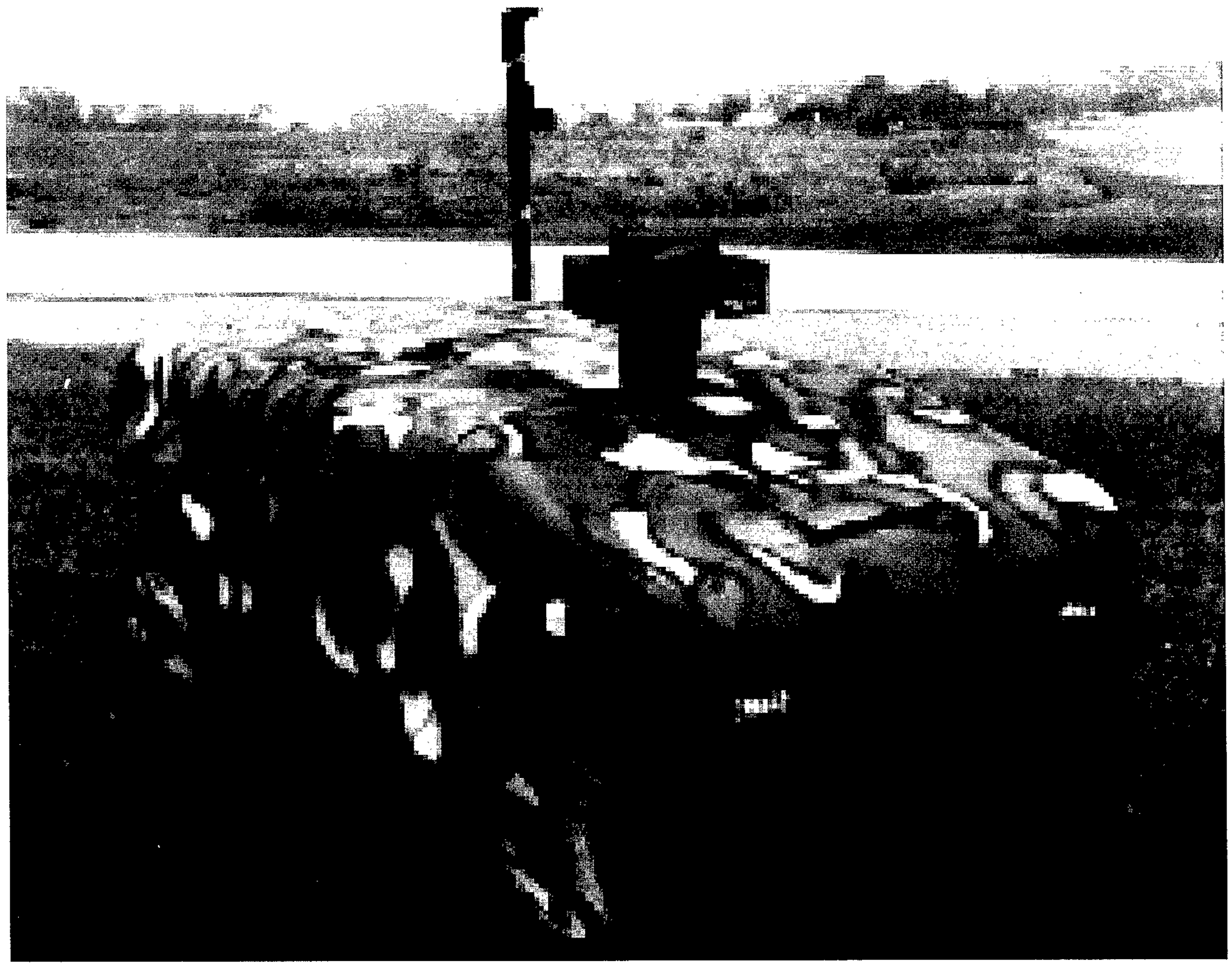
Tactical UGV



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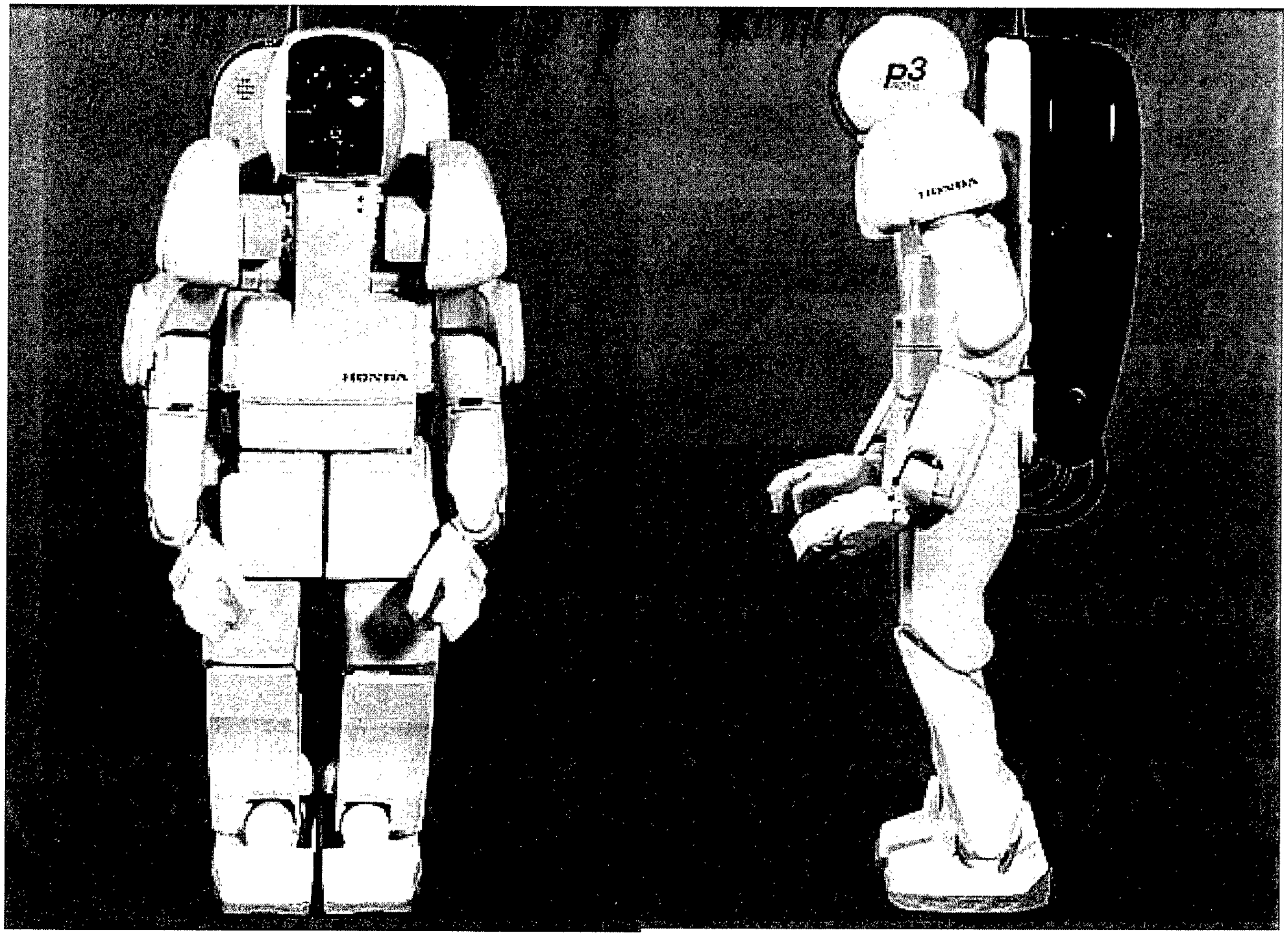
Androids



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Distributed Robots

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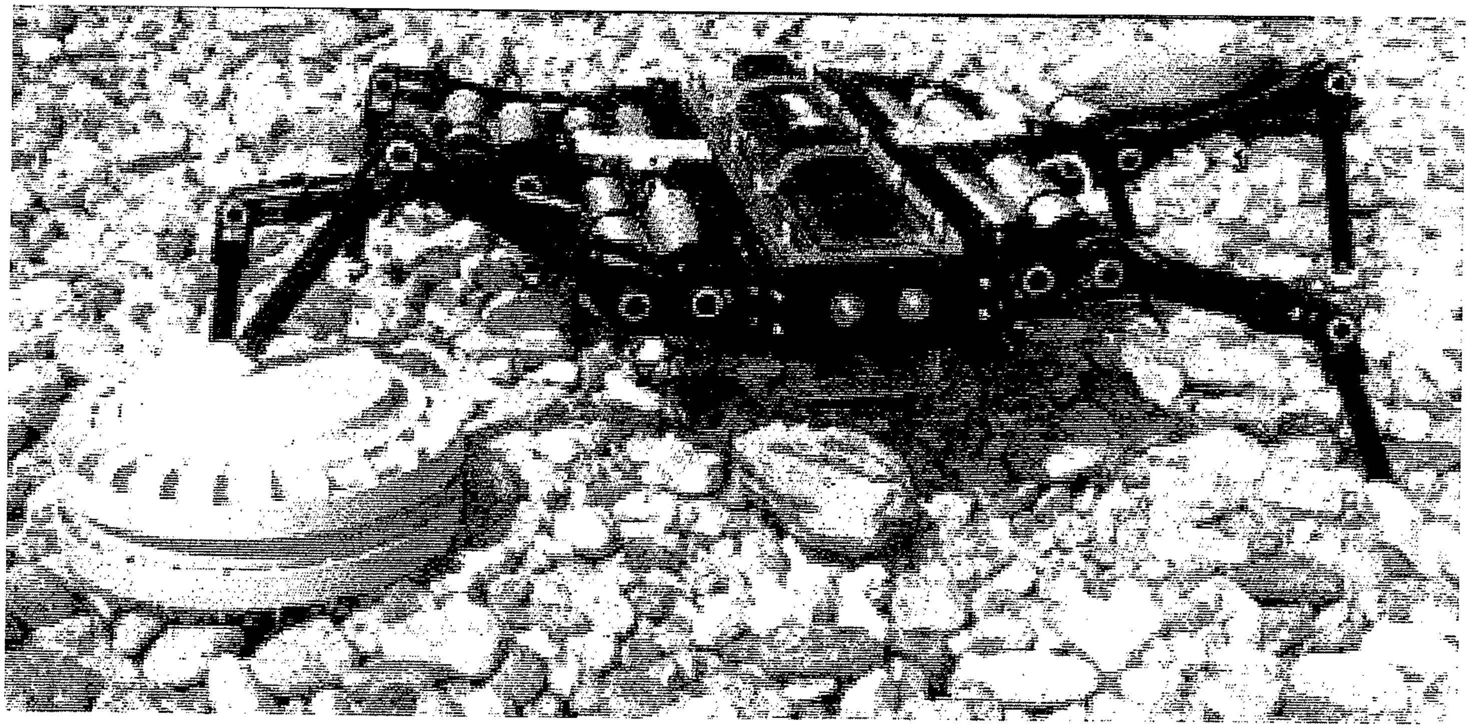
Aerial



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SDR Vision

Large Scale Results from
<u>many</u>
Small Scale Robots

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Research Issues

- Coordinated Control
- Networking/Communication
- Processing Power Allocation

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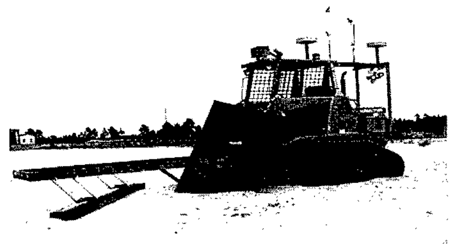
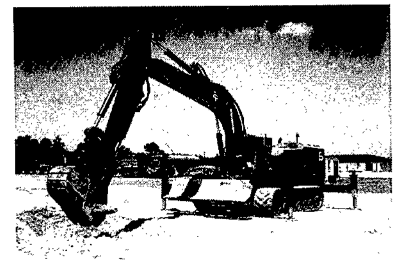
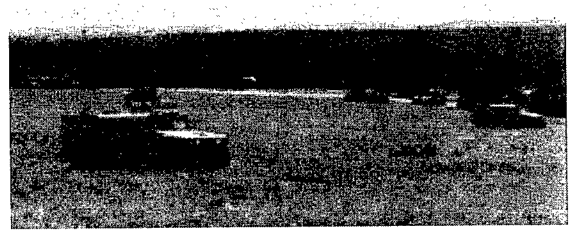
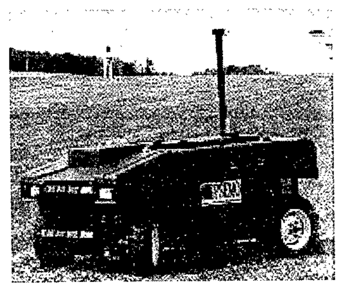
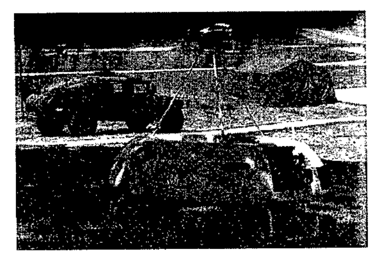
Unmanned Vehicles











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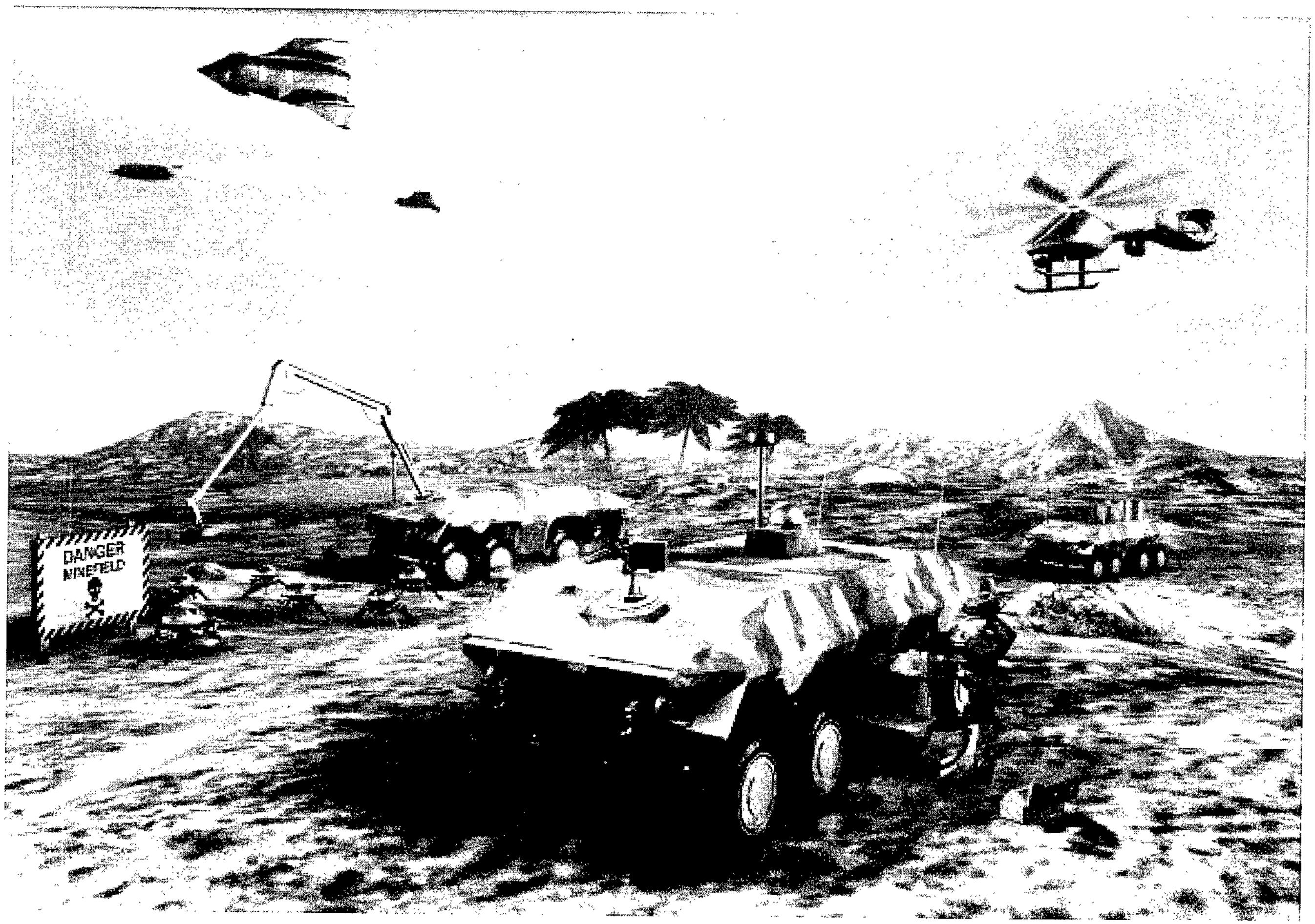
Autonomous Robots



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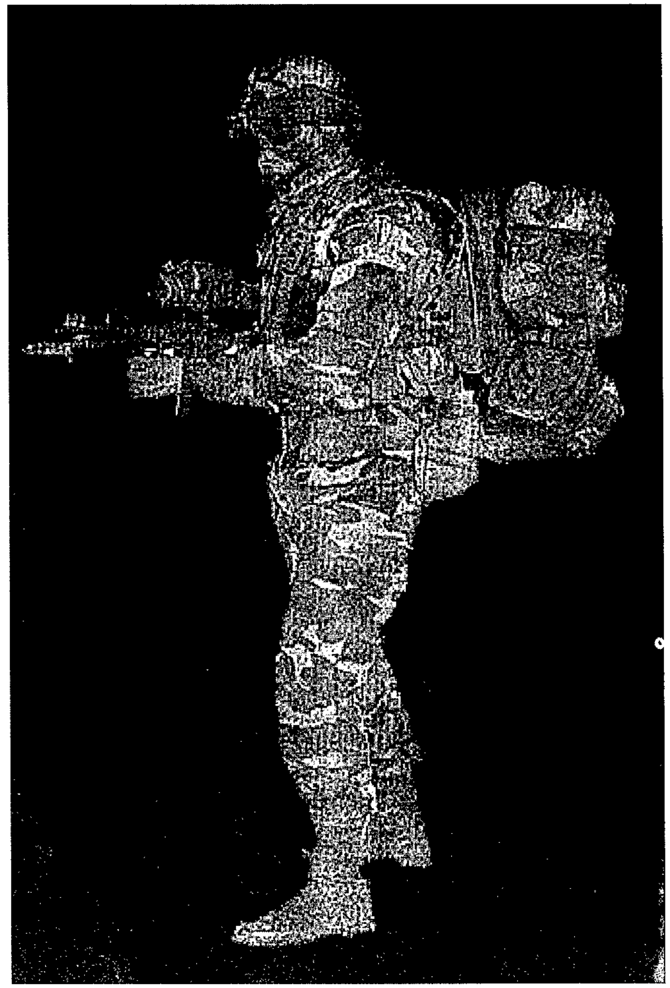
America's Army



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The Next Generation Internet Program

Mari Maeda
ITO

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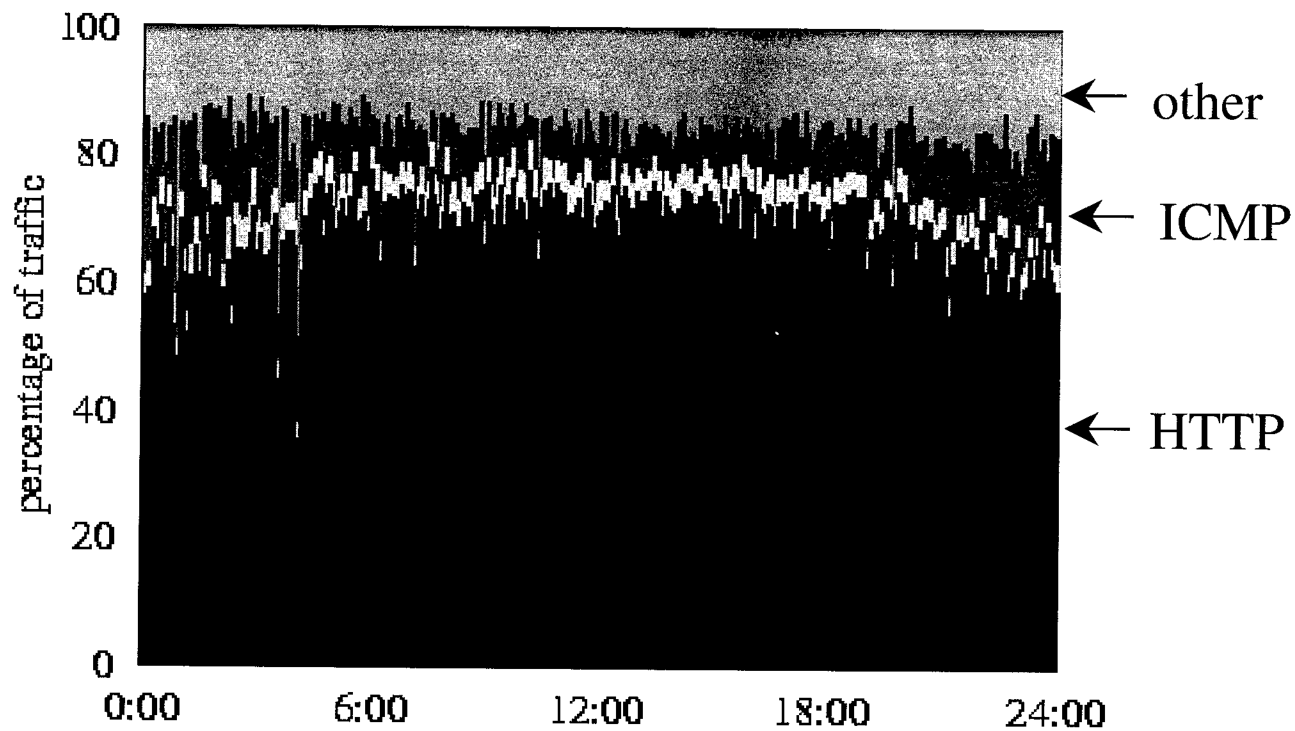
Today's Internet Traffic Makeup



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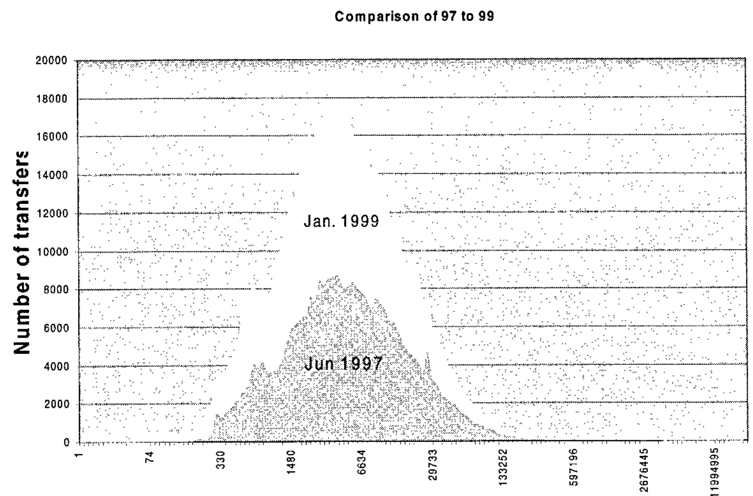
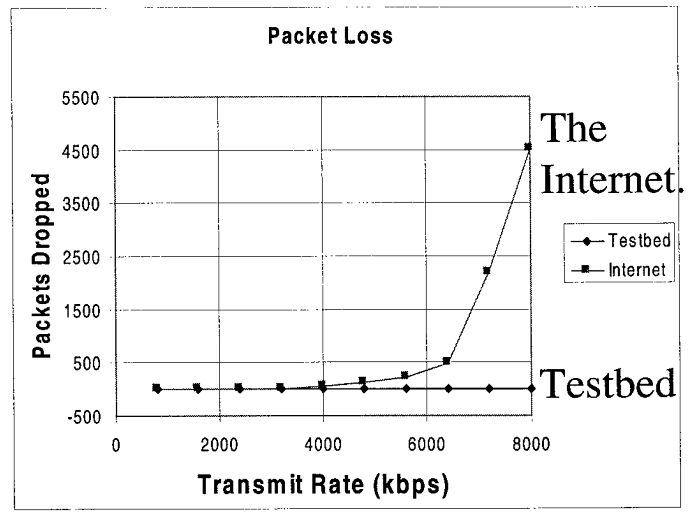
Today's Internet

Flow Size Distribution



Packet Loss vs. Transmit Rate



Cambridge to L.A.

Applications

Application binary	10's MB	Digital Video	20-90 Mb
High-Resolution Imagery	100 MB to GB	High-Definition TV	1500 Mbps

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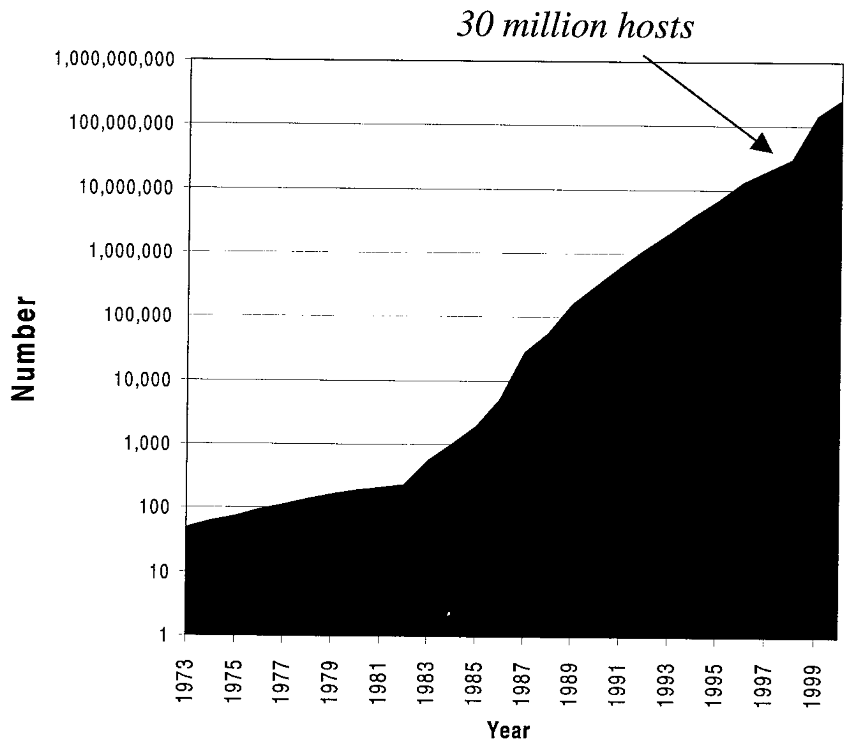
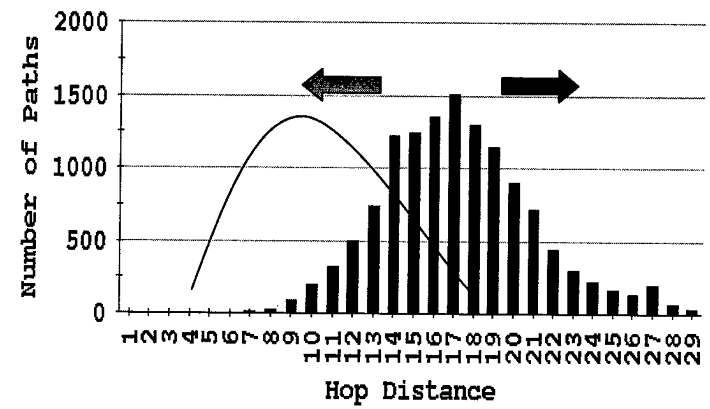
Scaling the Internet

How do we enable the Internet to scale?
(in size,speed,reach,apps)

Number of hosts connected to the Internet



Hop Number Distribution



mean hop distance = 16

- Increased loss probab.delay
- delay variation
- decreased security

110

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DARPA's NGI Goals

Develop next generation multiplexing and switching technologies that enable dynamic resource sharing between typical and high-end users

Supernet

Create tools that automate planning and mgmt functions enabling the growth of networks by a factor of 100 or more, while limiting the cost and complexity of network management and control

Network Engineering

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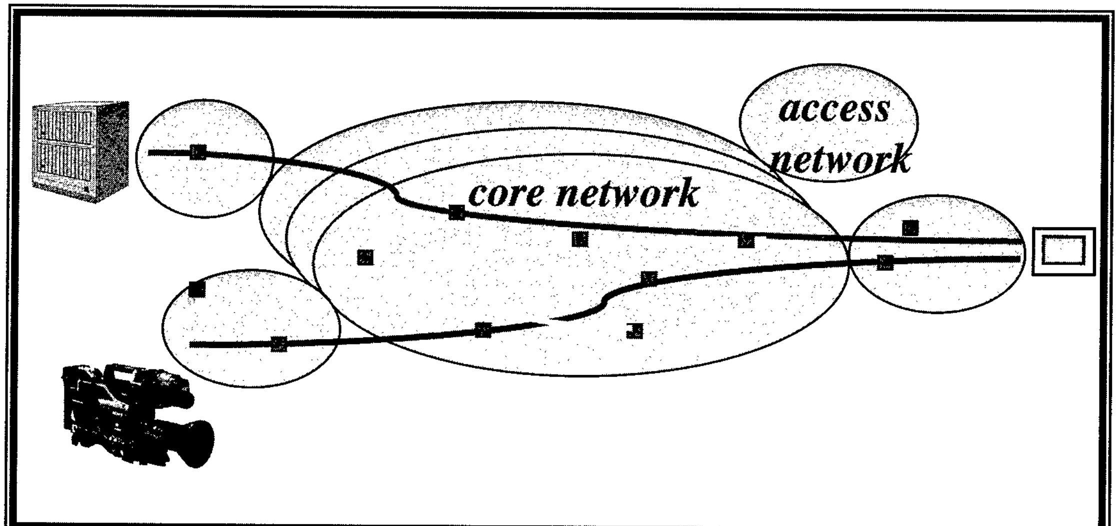
SuperNet Goals

To enable ultra-high bandwidth on demand over national networks, guaranteed over the shared infrastructure

Target: Multi-Gbps end to end

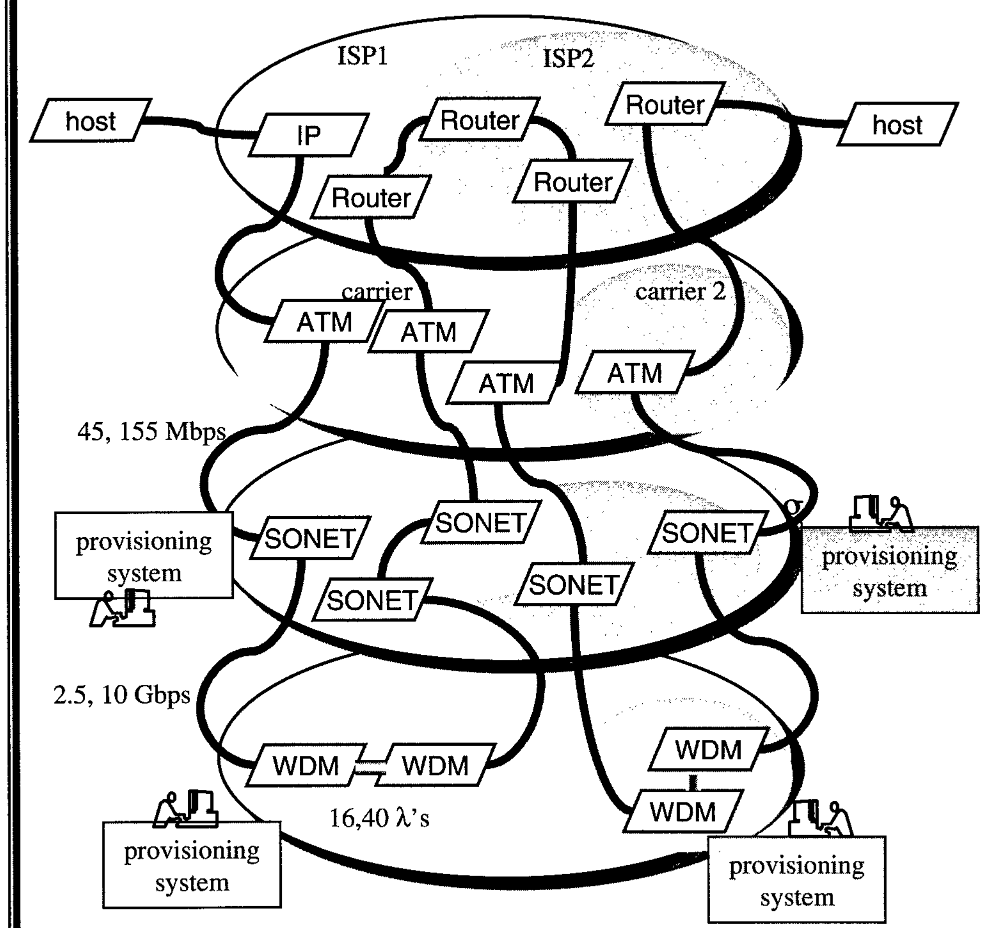


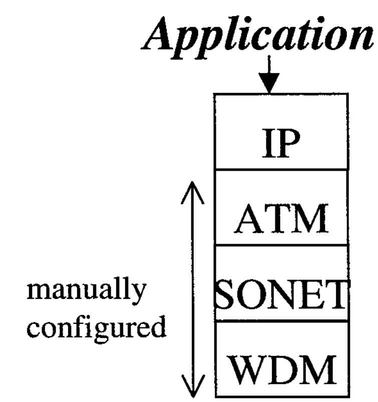
Approach:

- *Streamlined networking protocol stacks*
- *Dynamically reconfigurable/switched optical layer (opaque or electronic)*
- *"Transparency"*
- *New switching/ routing technologies and control algorithms*
- *Dynamic and high bandwidth local access*

ITO

SuperNet: Simplifying Protocol Stacks





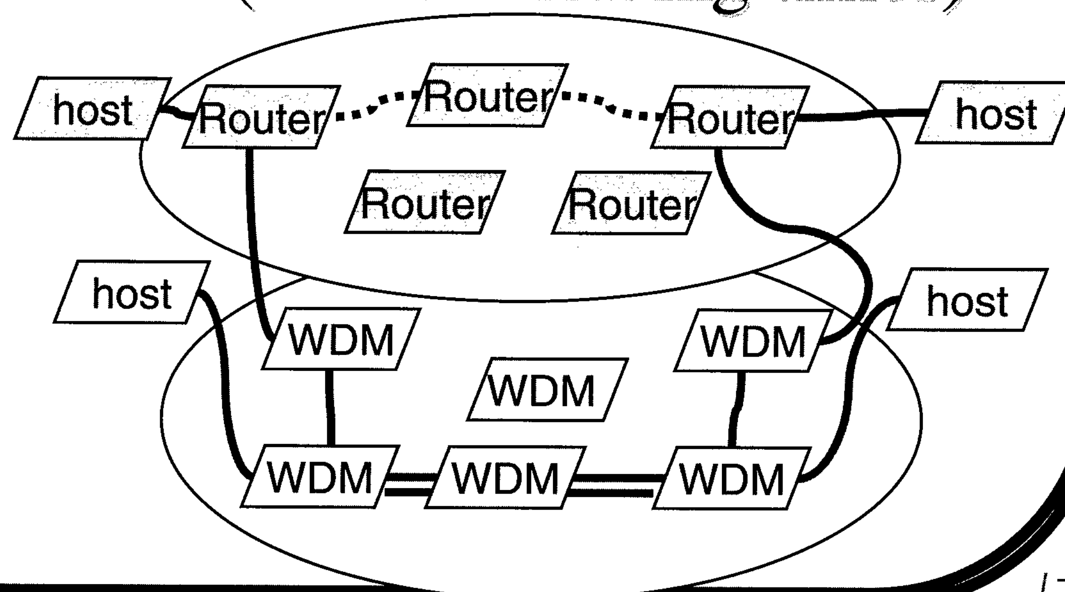
ITO

IP over WDM

- WDM based router bypass
- Optical Flow Switching -- based on aggregate traffic change
- Host-triggered path setup
- Optical burst switch (v. short holding times)

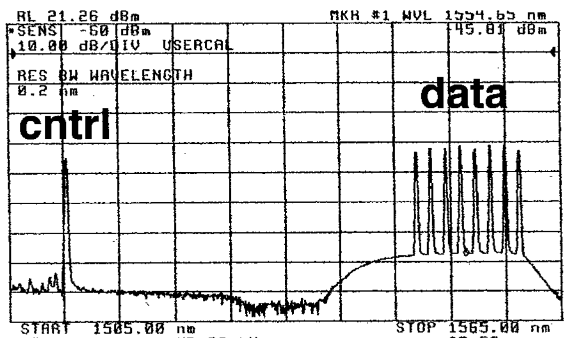
speed

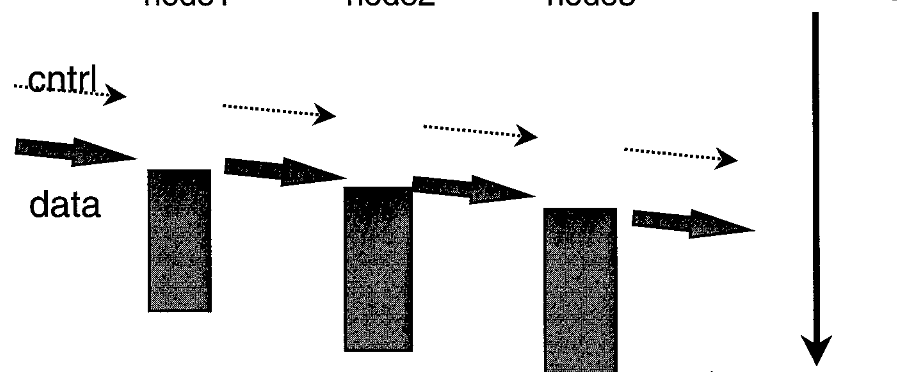
Dynamic Optical Layer
transparent, opaque, or
regenerated



ITO

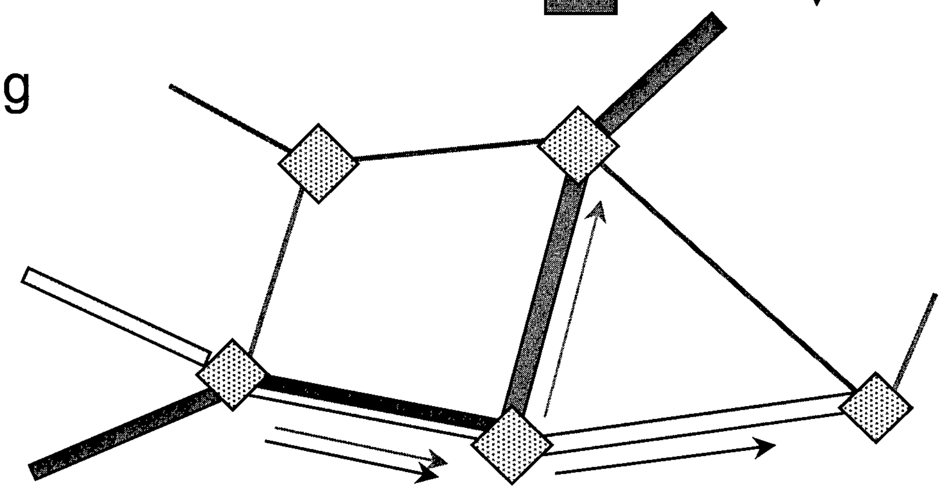
IP over WDM

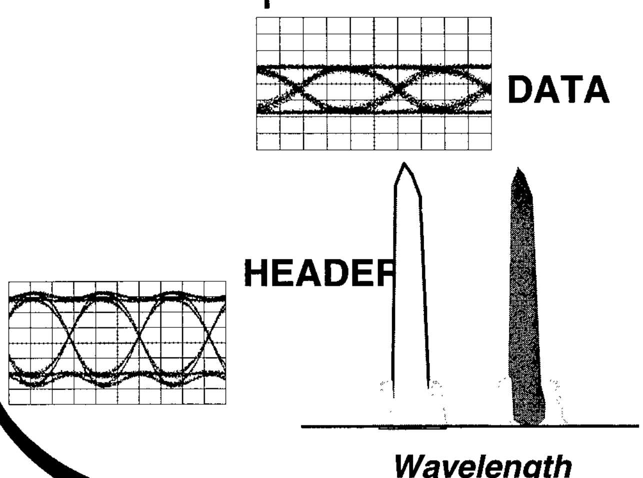




Optical Burst Switch

Optical Label Switching





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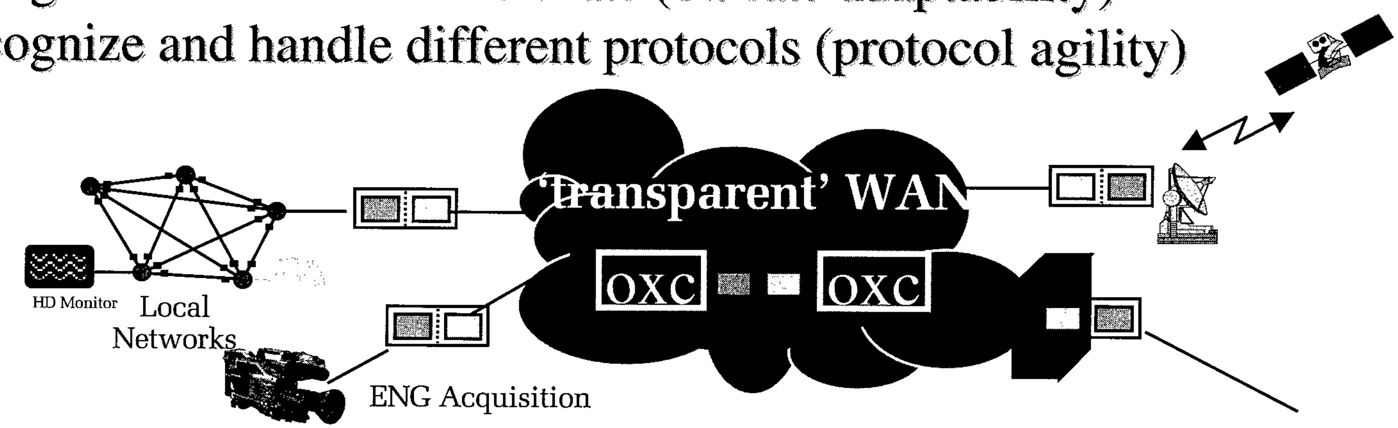
Bitrate and Protocol Transparent Modules

Modules at the core and the periphery of the network that can

- Recognize and lock to the bit rate (bit-rate adaptability)
- Recognize and handle different protocols (protocol agility)

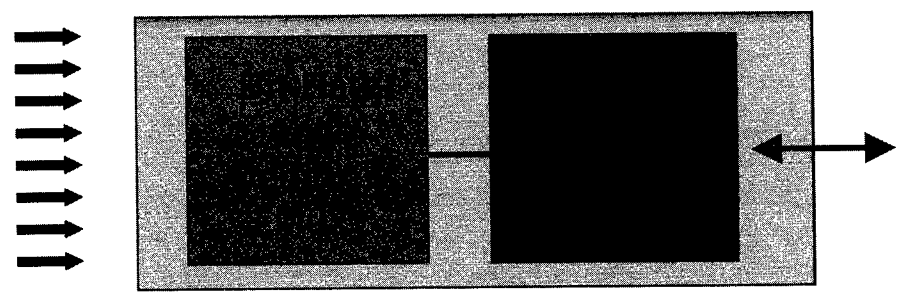


- *Dynamically reconfigurable or burst switched networks*
- *Automated network upgrades without replacing hw (lock-on or sw downloads)*
    - *Rapid deploymet*
    - *Adapt to new types of sensors, CPE's*
    - *Minimum inventory*
- *Development & testing of new protocols*

ITO

Universal Network Access Module

- Target bit range: 100 Mbps to 3 Gbps initially (10 Gbps later)
- Handle a variety of protocol classes at Layer 1 - 3
  - OC3/12/48c ATM / SONET
  - OC3/12/48c IP/SONET
  - Gigabit ethernet
  - SMPTE 25/292
  - IEEE 1394 (firewire)
  - G-Link
  - FDDI
  - Fibre Channel
  - "ngi protocol" e.g. IP/WDM



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Network Engineering

- Adaptive control
- Self-management
- Modeling and simulations
- Network visualization

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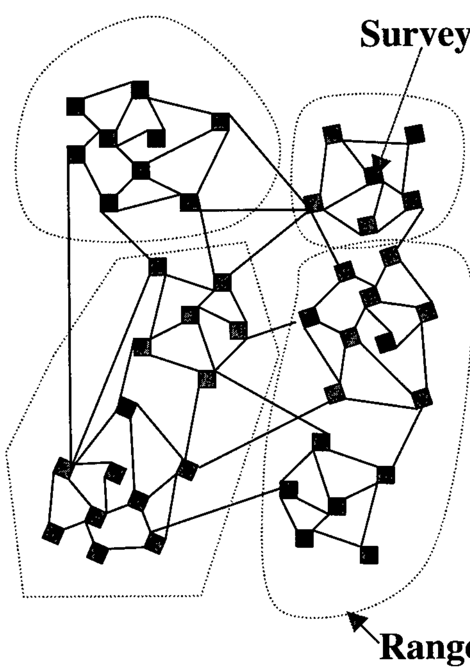
Network Engineering: Adaptive Network Management Project

Large-scale network fault isolation



Self-configuring network monitors

- Surveyors map neighborhood
- They coordinate with other surveyors to adjust their ranges
- Careful multicast based self-organization
  - Continuous range expansion
  - Range description exchange
  - Back off
- …eventually adapts to surveyor failure, network partitions

Adapts to network fault (link cut, node failure, congestion, network partition) and surveyor failure.

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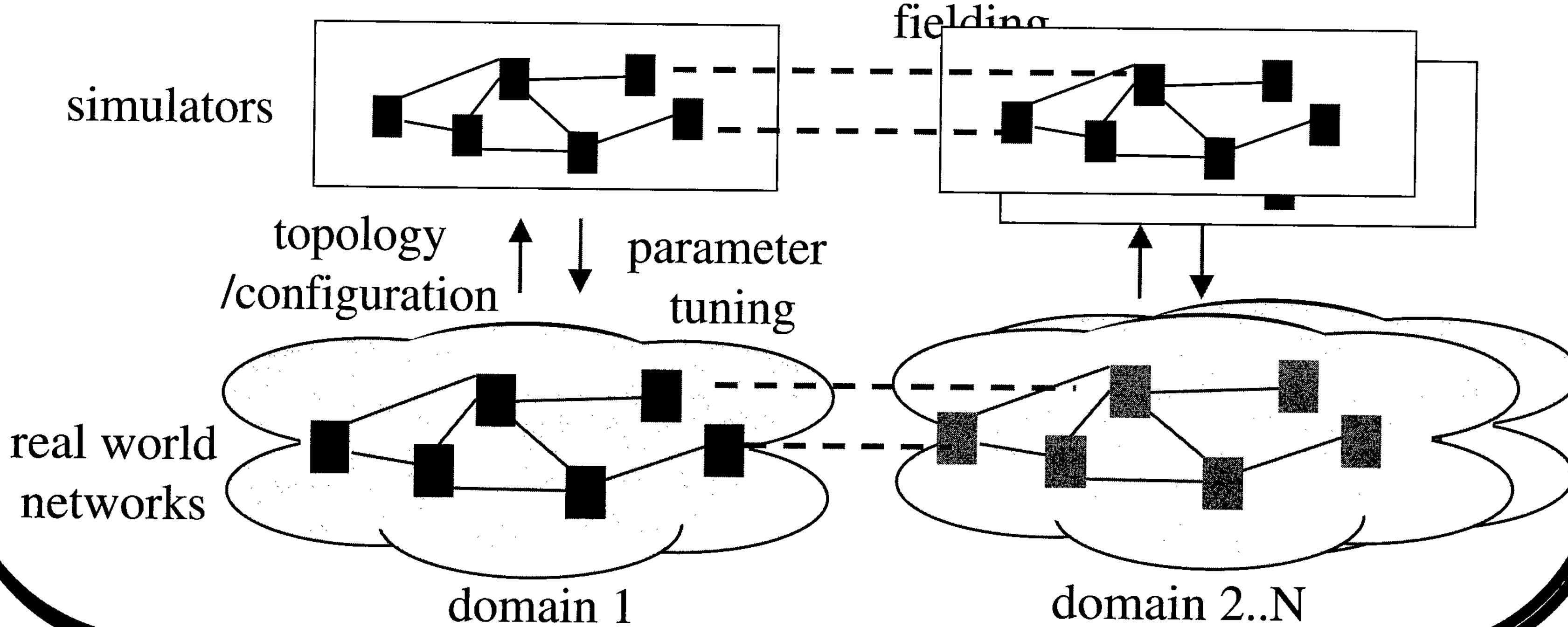
Network Engineering: Real-Time Network Simulations

From: Off-line
- Yesterday's traffic situation guides today's provisioning
- Problems fixed after occurrence

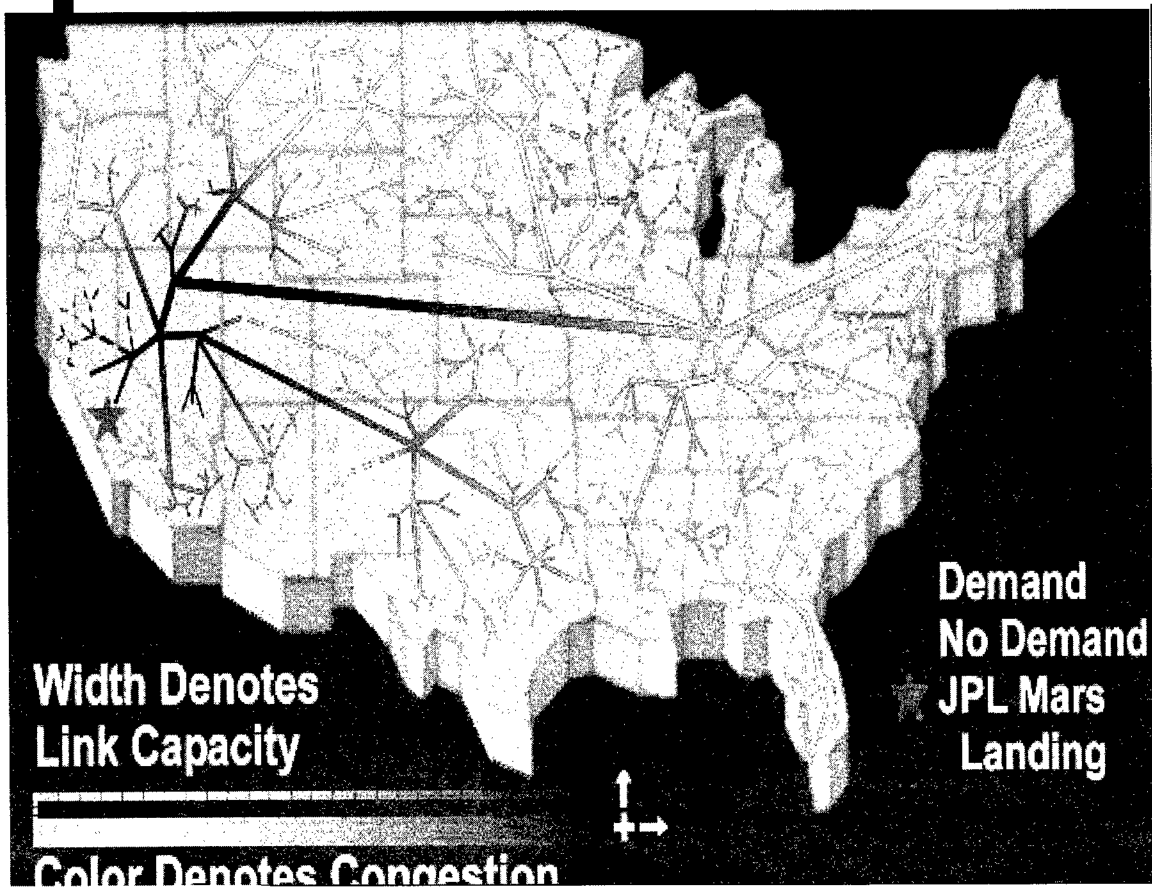
To: Realtime
- Live parameter tuning
- Large-scale changes and repair validation prior to fielding



ITO

Adaptive Web Caching Project
Target Problem: **"Hot Spots"**

Hundreds of thousands of clients fetching the **same data** from the **same server** at about the **same time**



Today:
- Happens few times a year
- Manually create replic. sites
- The Internet has yet to meet the challenge of simultaneous demands from millions of users

Tomorrow:
- Daily occurrence?
- Need demand-driven data dissemination and self-organizing caches e.g. content based routing protocol, cache group management protocol

Network Engineering: Network Monitoring, Analysis and Visualization

- Monitor and automate the discovery of the topology and traffic behavior of the Internet and future networks on a global scale.
- What makes this hard:
  - No central authority
  - Scale (span and speed)
  - Capturing dynamic behavior
  - Visualization

Tools :

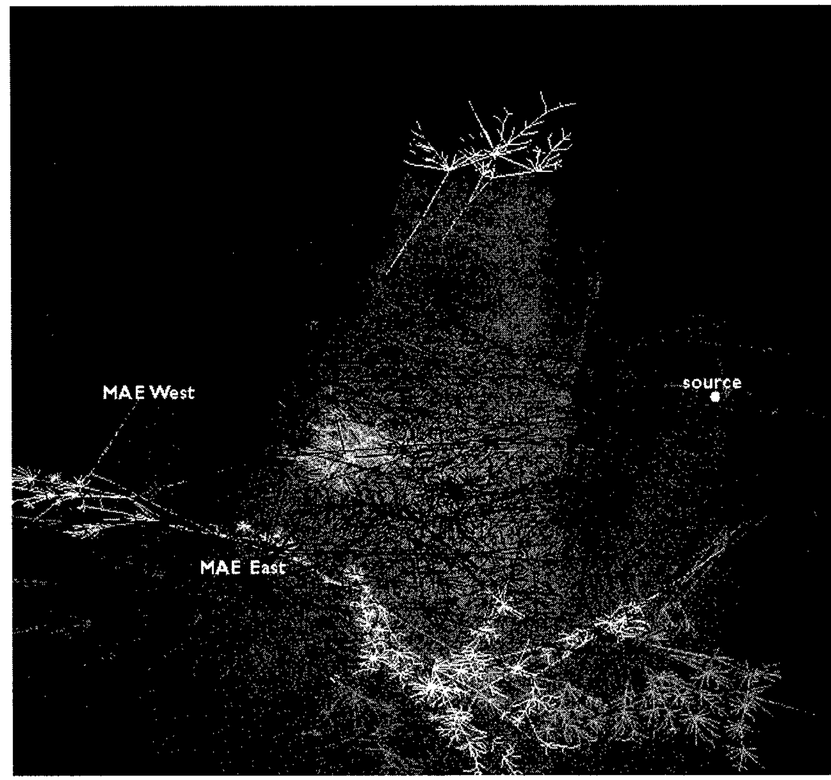
"skitter" (active measurements: performance, topology)

"coral" monitors (passive measurements over high speed links)

ITO

Network Tomography

- Network "Radar": Global connectivity information
- Measure IP paths ("hops") from source to MANY (~104) destinations
- Use 52 byte ICMP echo requests (every 30 min.) as probes
- Challenges:
  - Pervasive measurement with minimal load on infrastructure
  - Visualization



UCSD/CAIDA
(Cooperative Association for Internet Data Analysis)

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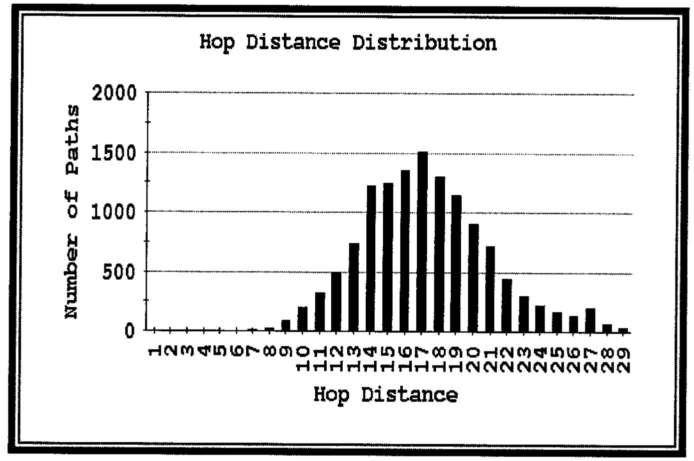
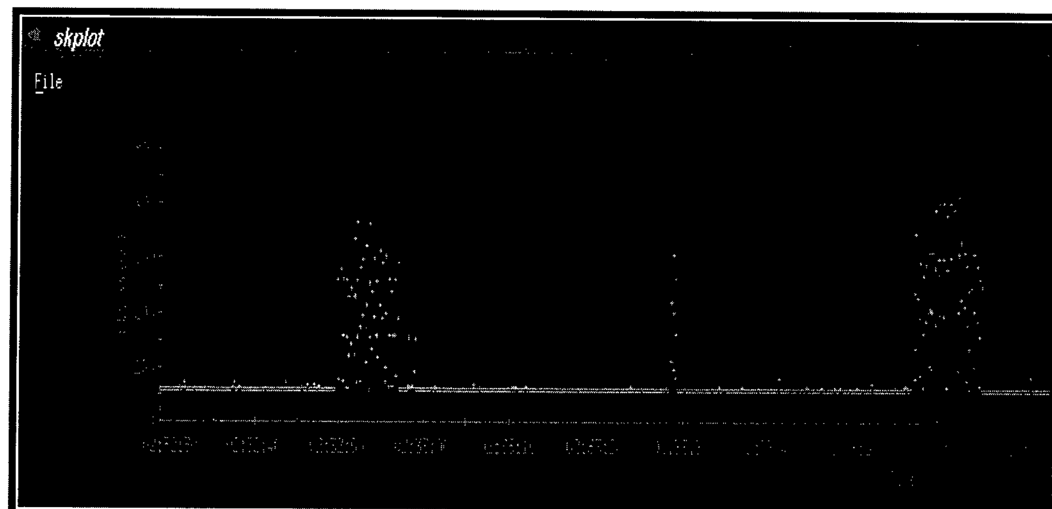
Internet Tomography

Hop count histogram



Temporal behavior



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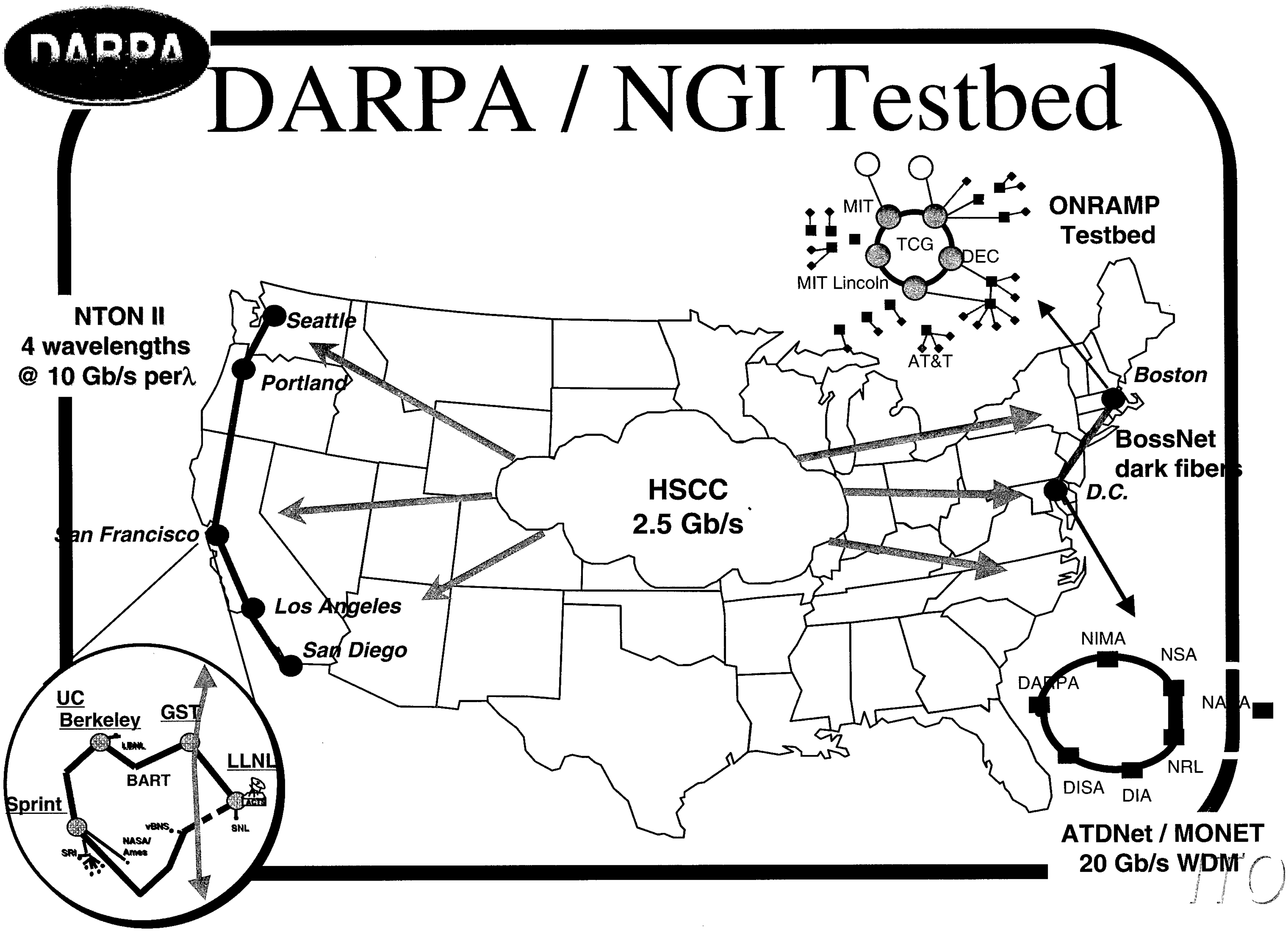
DARPA / NGI Testbed



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DARPA

Government-Wide NGI Program

Presidential Initiative -
Start FY1998; 3 year base + 2 year option

Participating Agencies:
DARPA, NSF, NIH/NLM, NIST, NASA, DOE

Goals:

- Networking Research
- Testbeds (SuperNet, vBNS, NREN, ESNET, DREN)
- Revolutionary Applications

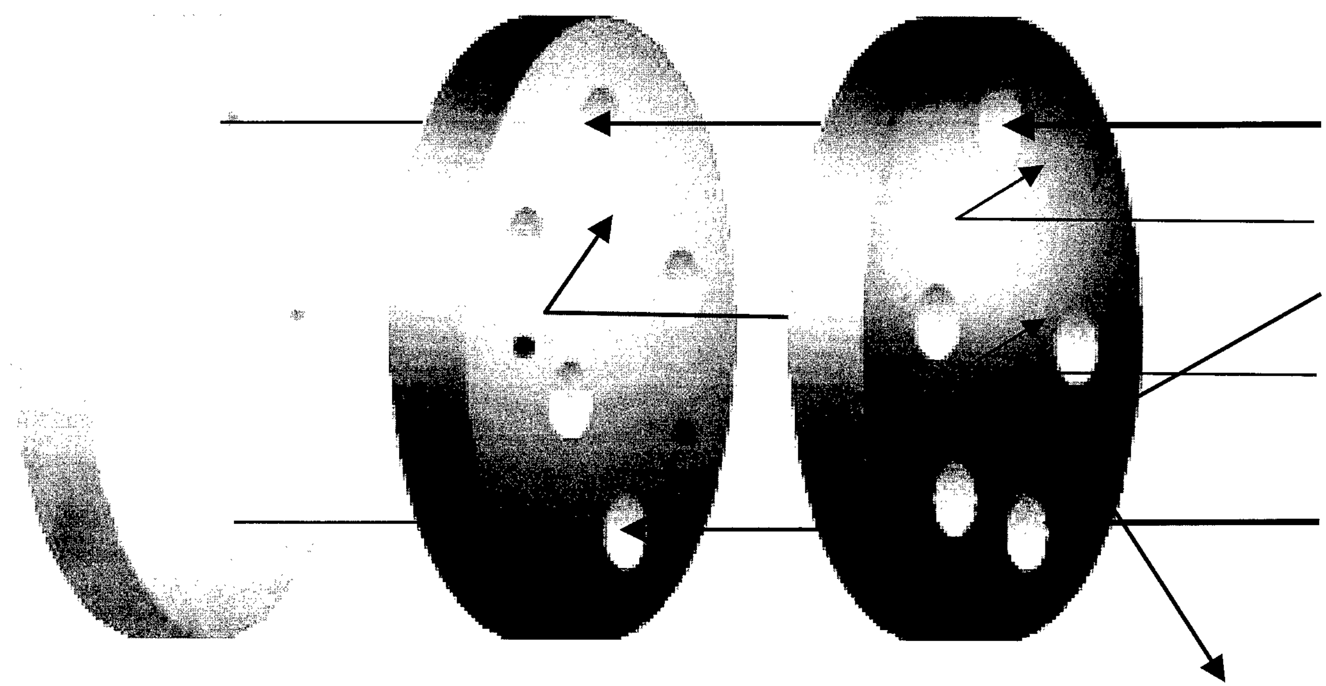
Inherent Information Survivability

Gary M. Koob
DARPA/ITO
gkoob@darpa.mil

ITO

Layered Defense

Tolerate **Detect** **Prevent**



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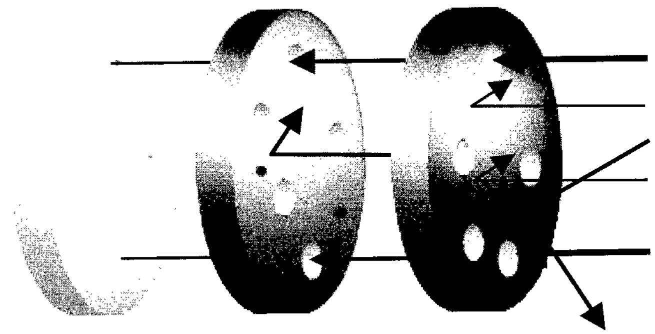
DARPA Strategy

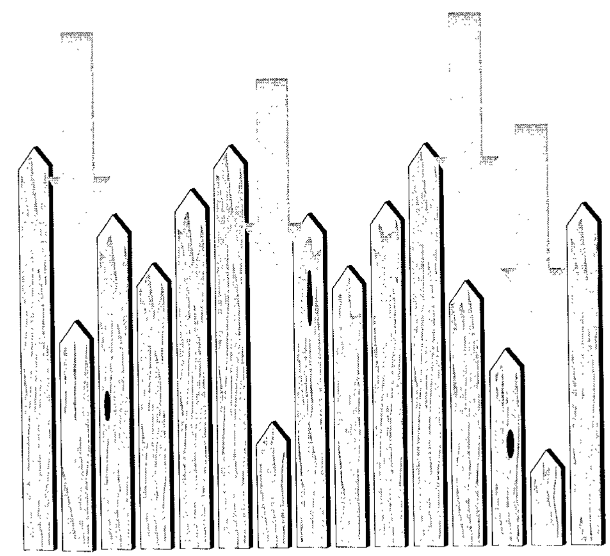
ITO

Address Critical Technology Gaps



ISO

Integration for Balanced Protection



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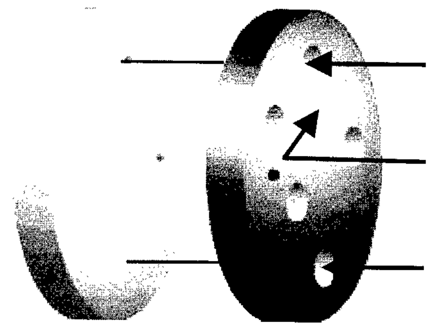
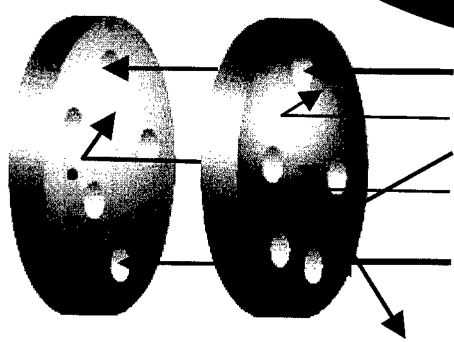
Roadmap

Inherent Survivability
1999-2003



ISO Info Assurance
1997-2000



Information Survivability
1995-1999

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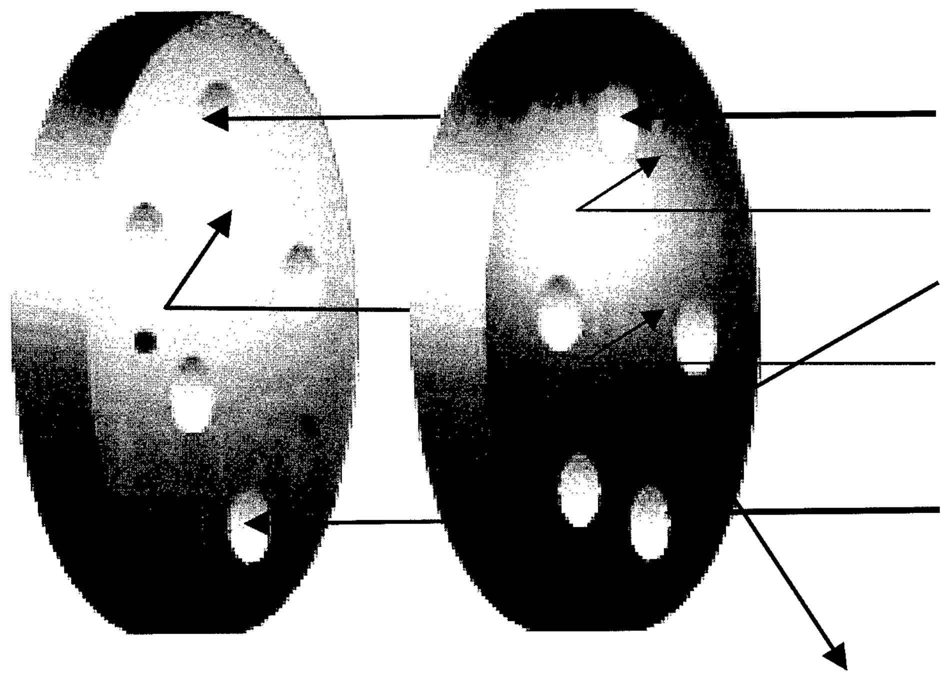
Accomplishments

Local Detection *Strong Barriers*



Information Survivability Program

1995-1999

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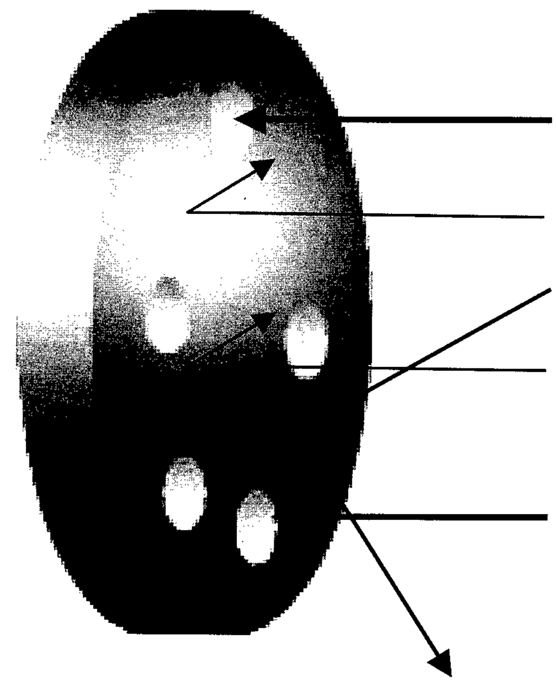
Strong Barriers

Develop strong barriers to penetration at all system levels



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Network: DNS Security

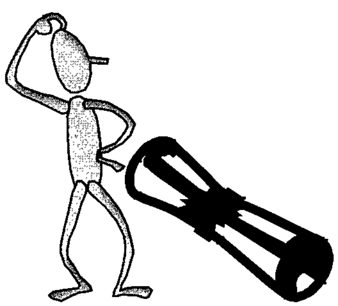
Authenticated Name-Address Mappings

www.darpa.mil?

(root) says: **mil is 164.117.176.1**

.mil says: **darpa is 192.5.18.99**

darpa says: **www is 192.5.18.70**



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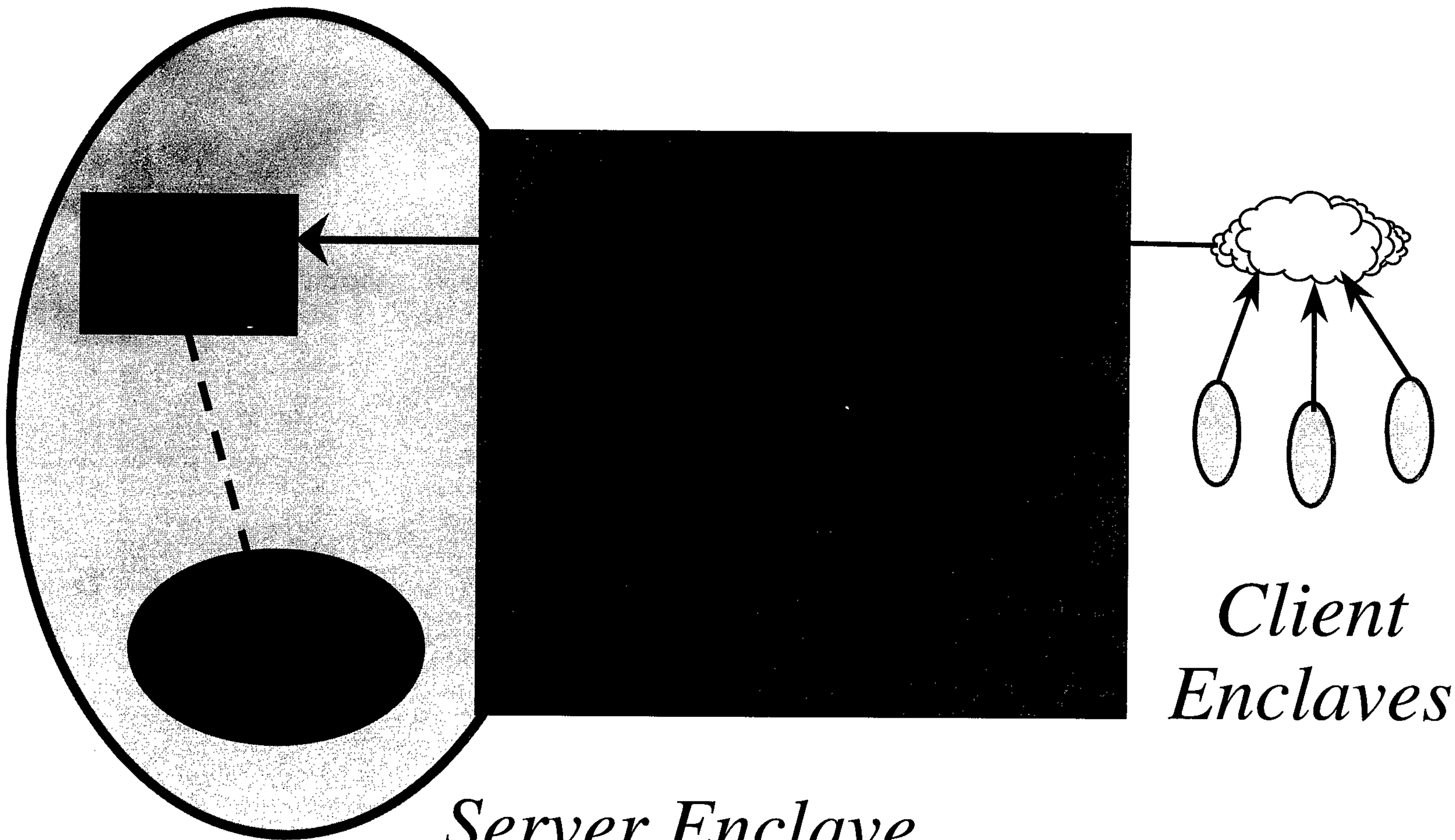
Middleware: CORBA



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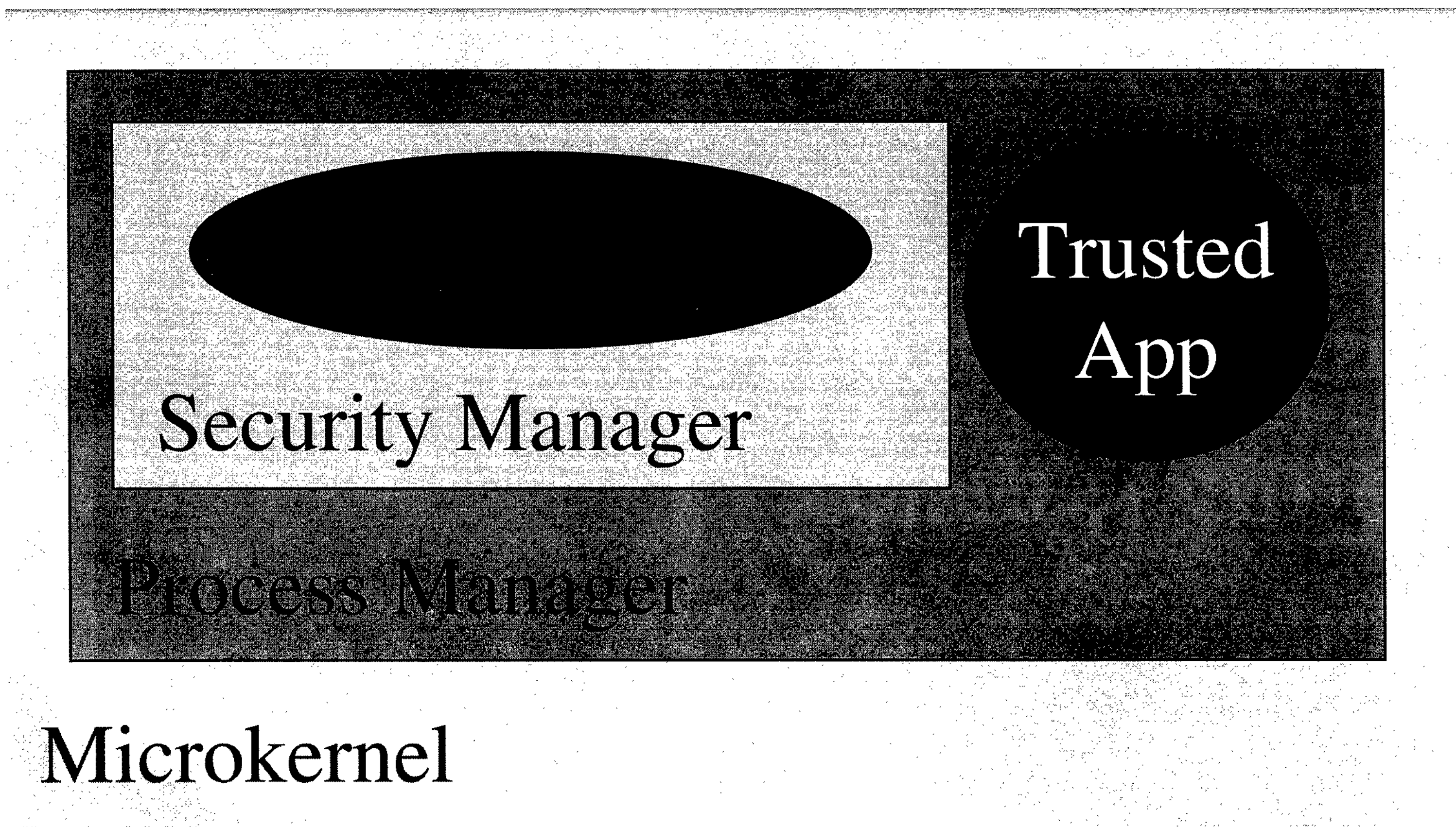
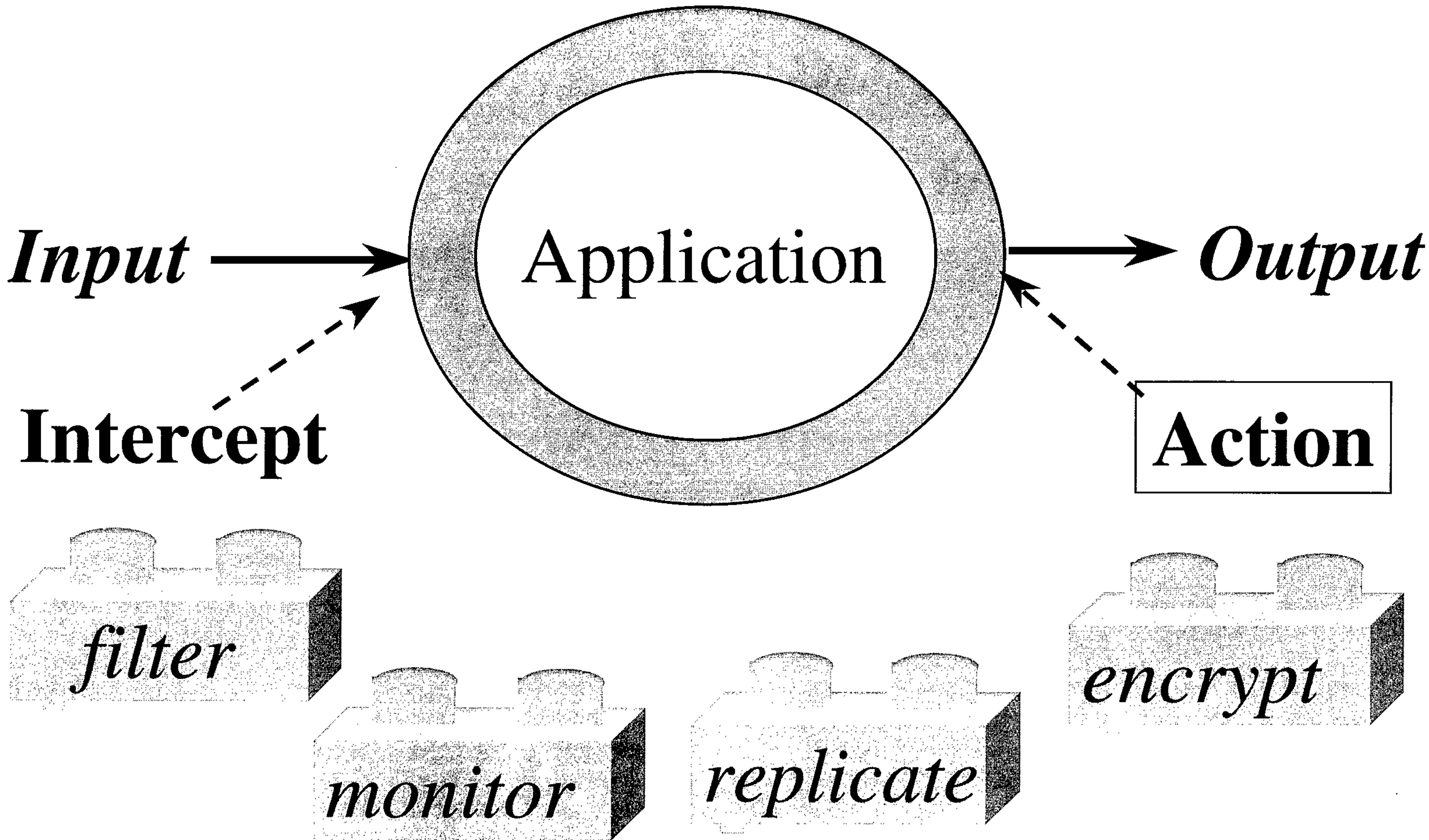
OS:Nested Processes



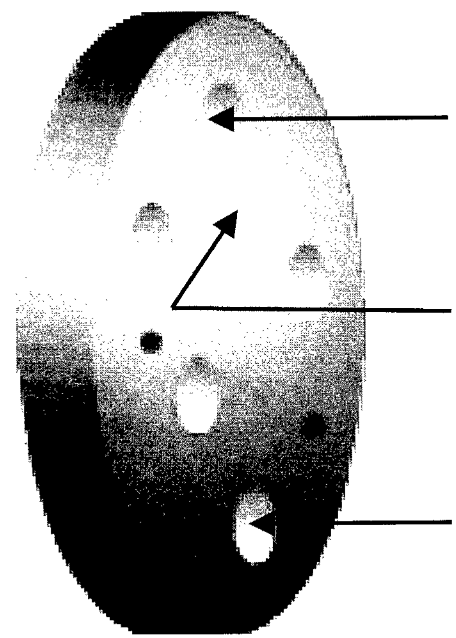
ITO

Application: Wrappers



Local Intrusion Detection

Detect attacks locally with high confidence and low false alarm rate



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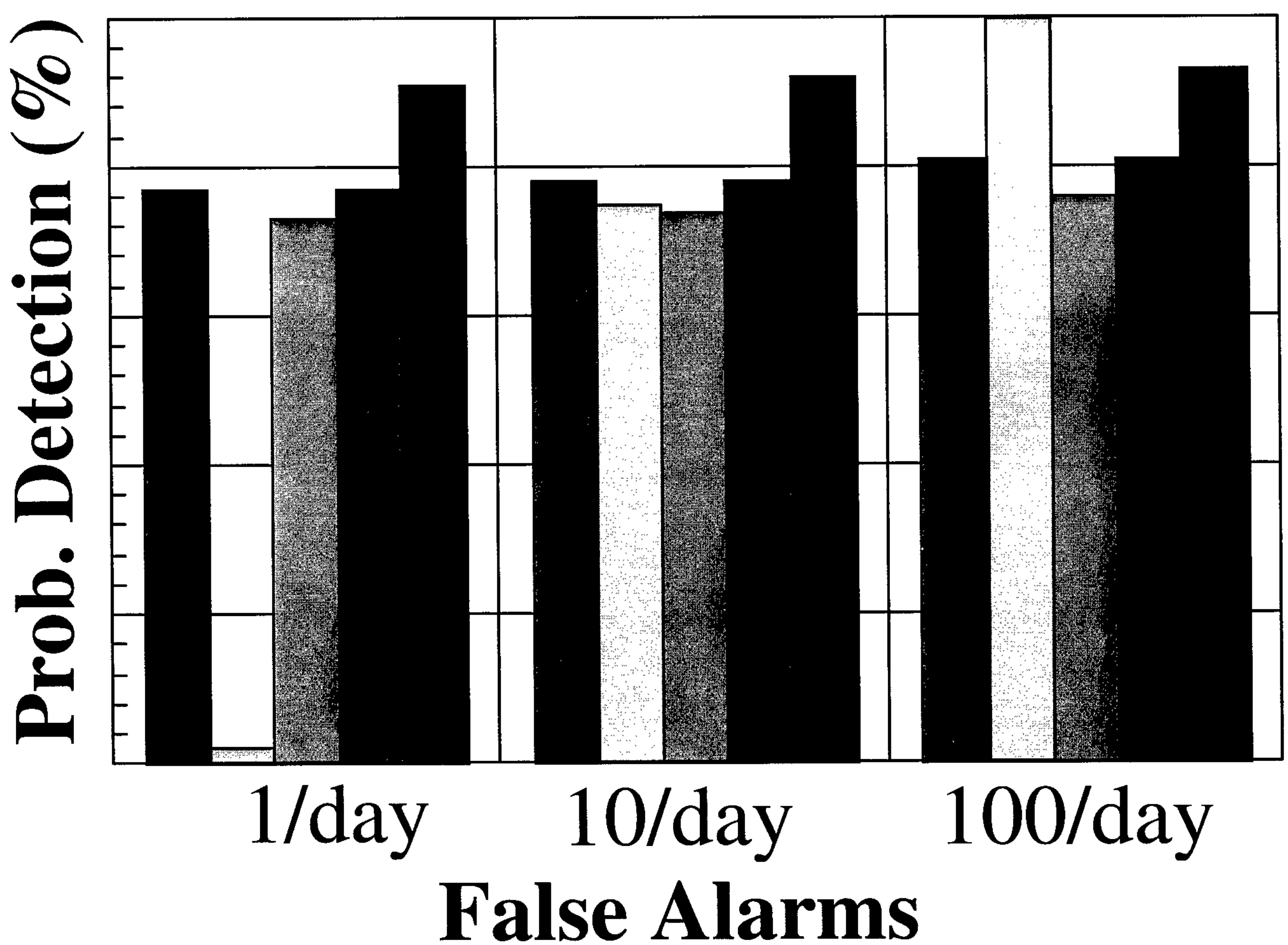
Intrusion Detection

- State-of-the-Practice
  - Pattern matching on known attacks
- Program focus
  - Statistical Anomaly Detection
  - Model-Based Profiles

Detect Previously Unknown Attacks

Sample Results



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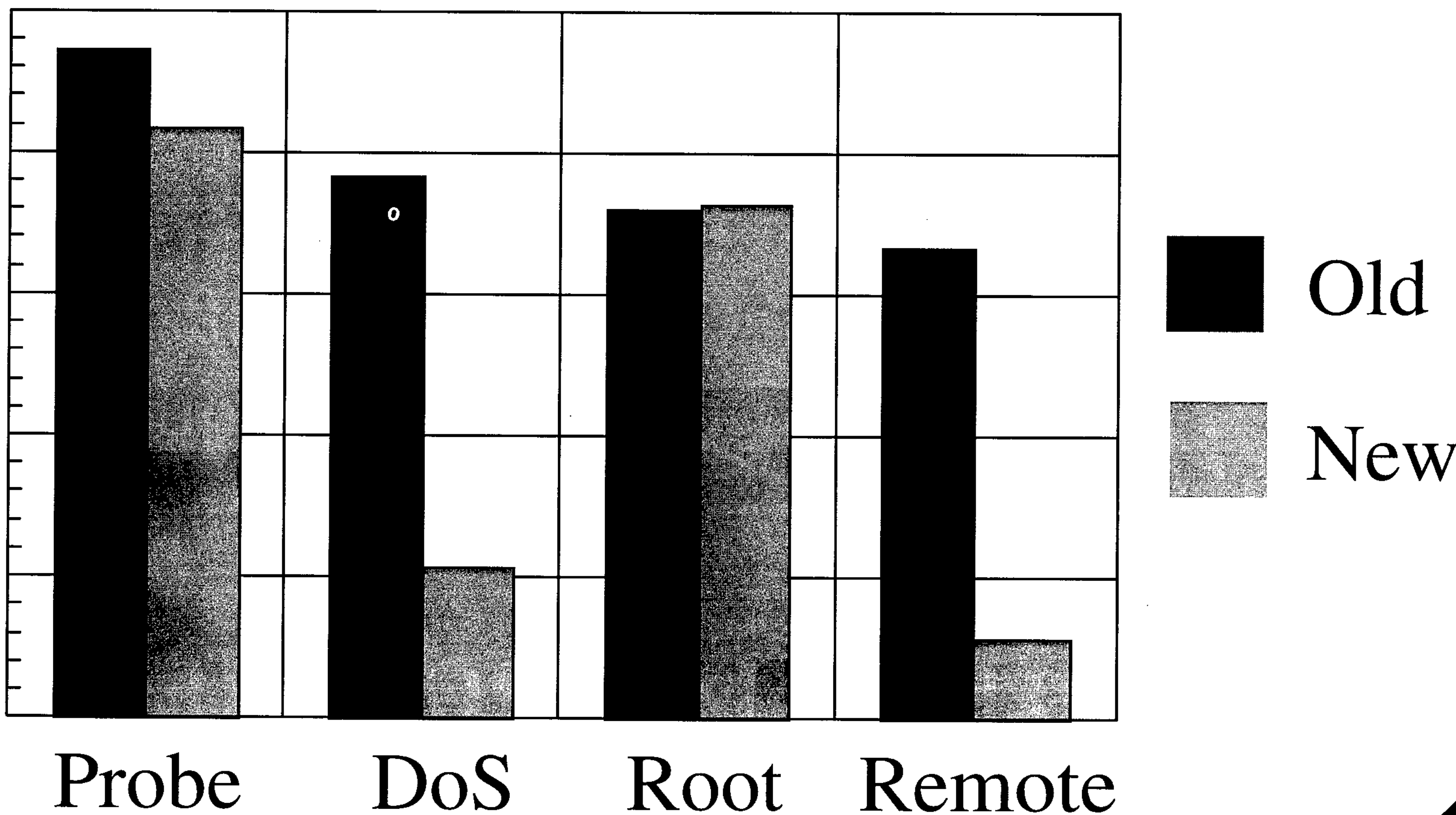
Old vs New Attacks



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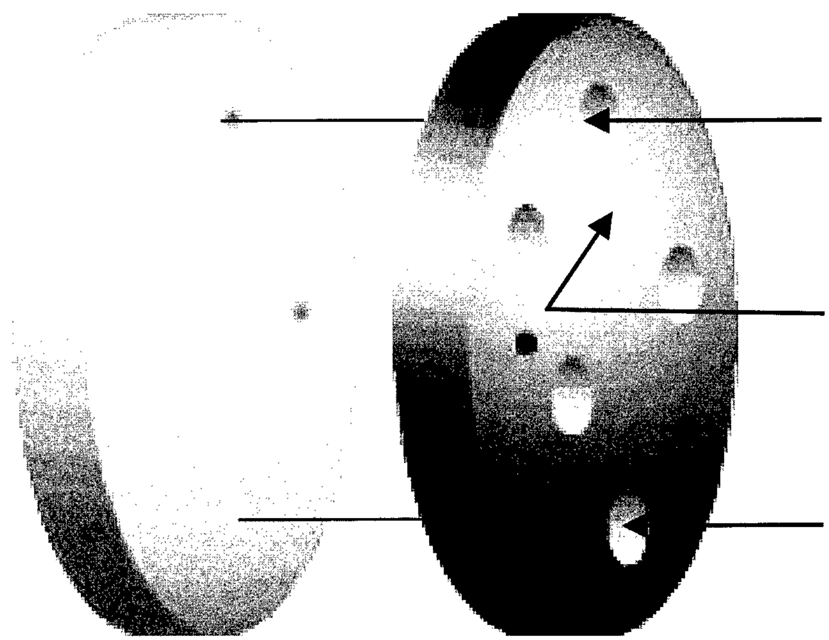
New Directions

Intrusion Tolerance *Global Detection*

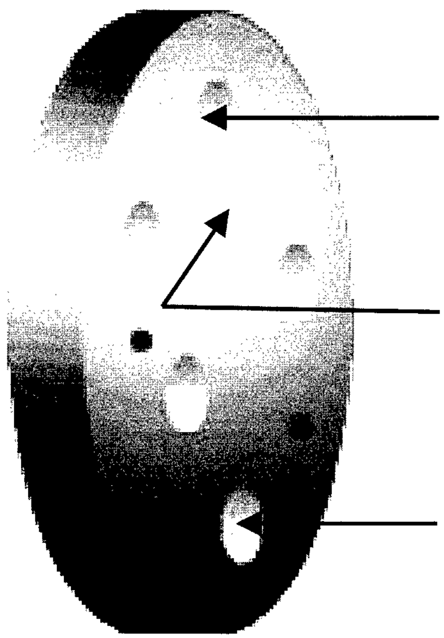


Inherent Survivability Program

1999-2003

DARPA

Global Detection



Distinguish events of elevated significance from those of only local interest

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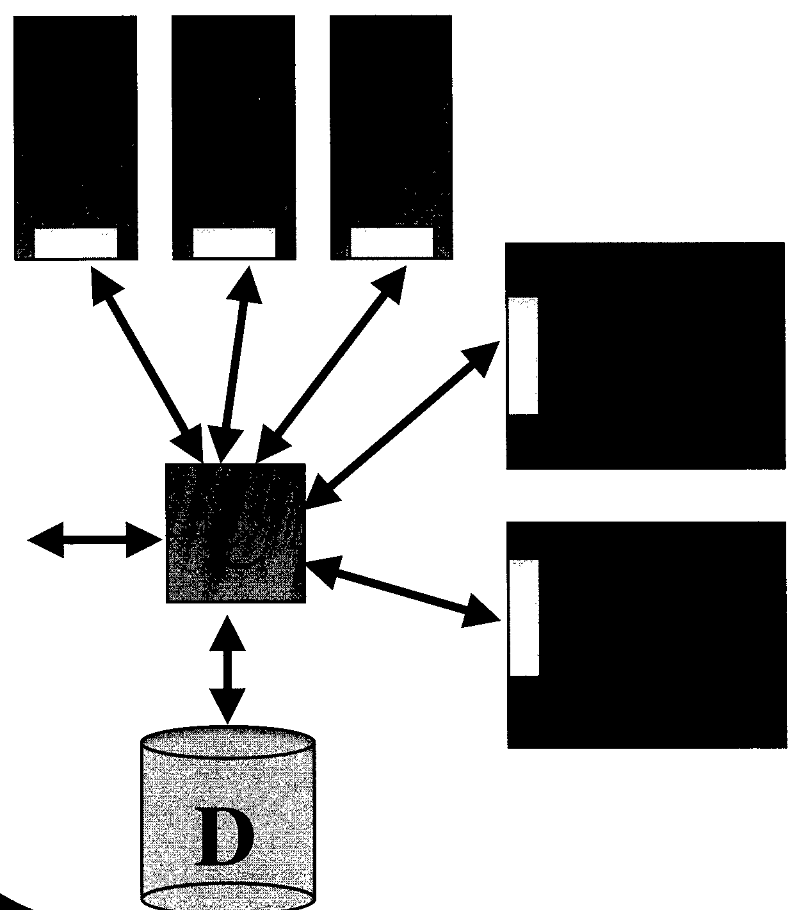
Common Intrusion Detection Framework



E Event Generator

A Event Analyzer

D Event Database

C Controller

Standard API

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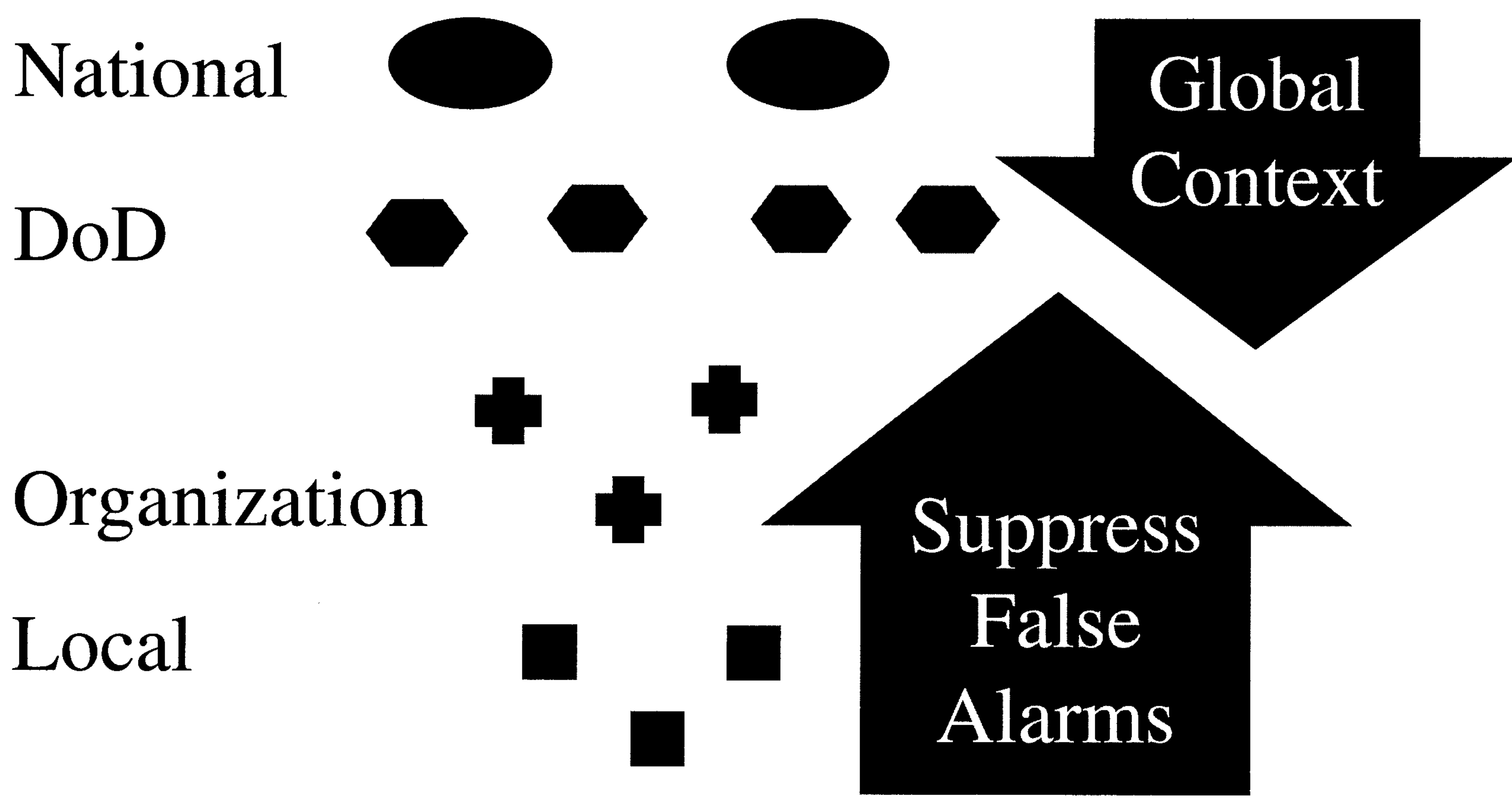
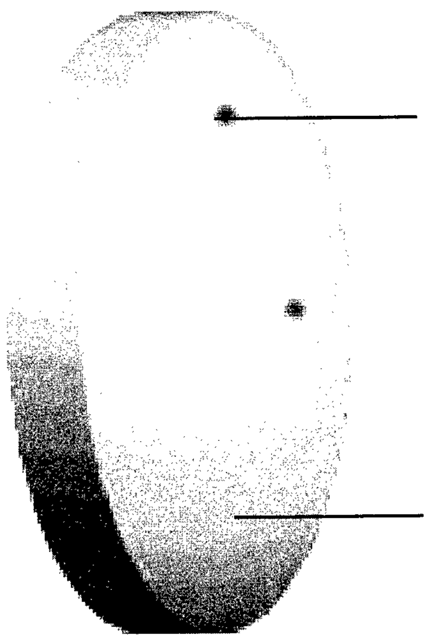
Intrusion Assessment



Intrusion Tolerant Systems



Maximize ability to continue critical operations following partial compromise

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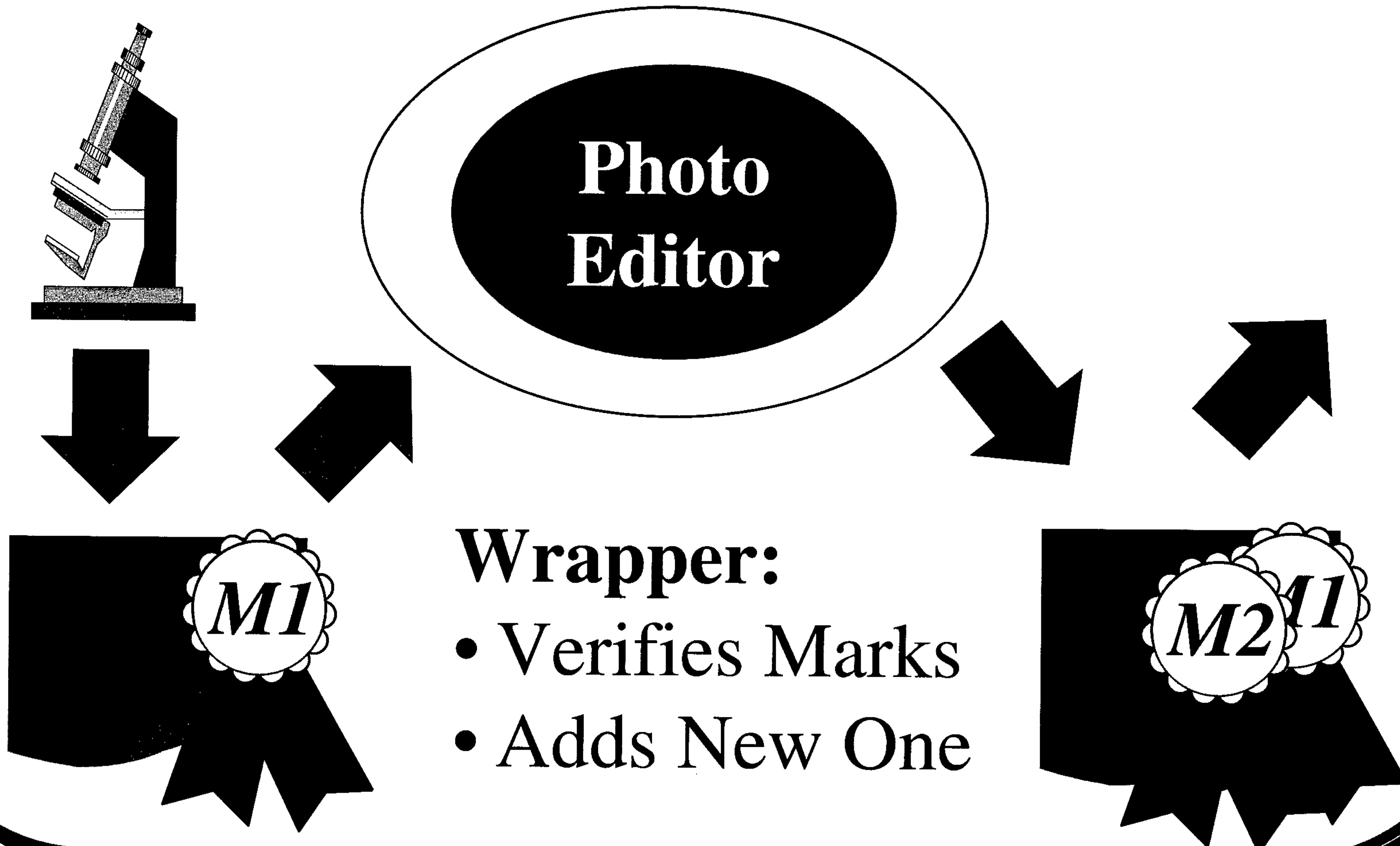
Data Integrity Marks



Wrapper:
- Verifies Marks
- Adds New One

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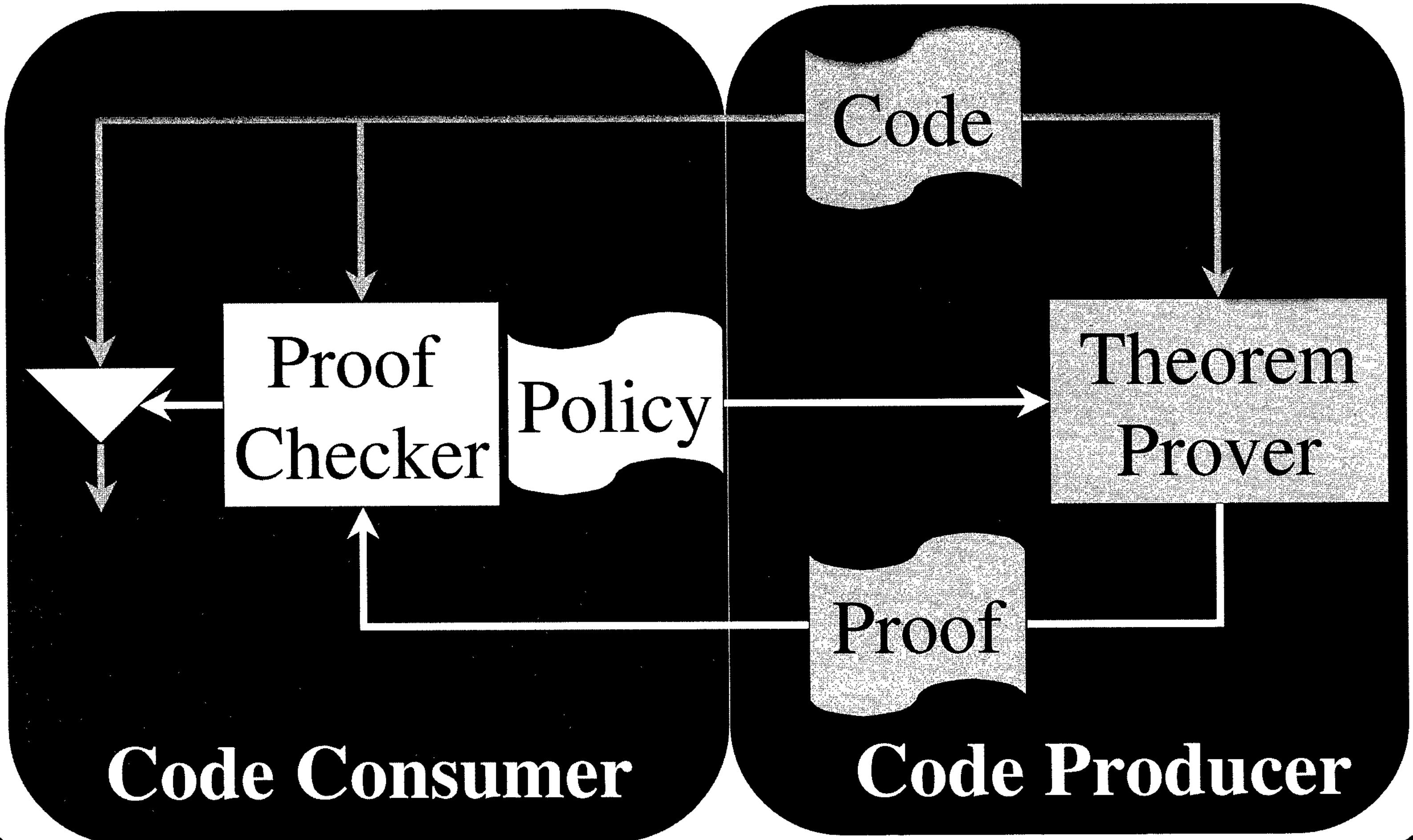
Proof Carrying Code



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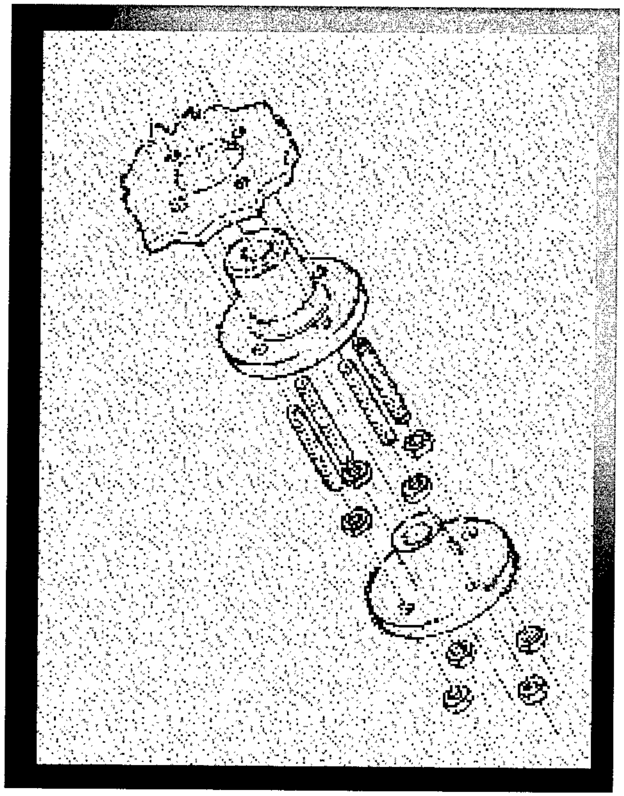
Tolerant Software

Analogy to Mechanical Parts



Tolerate:

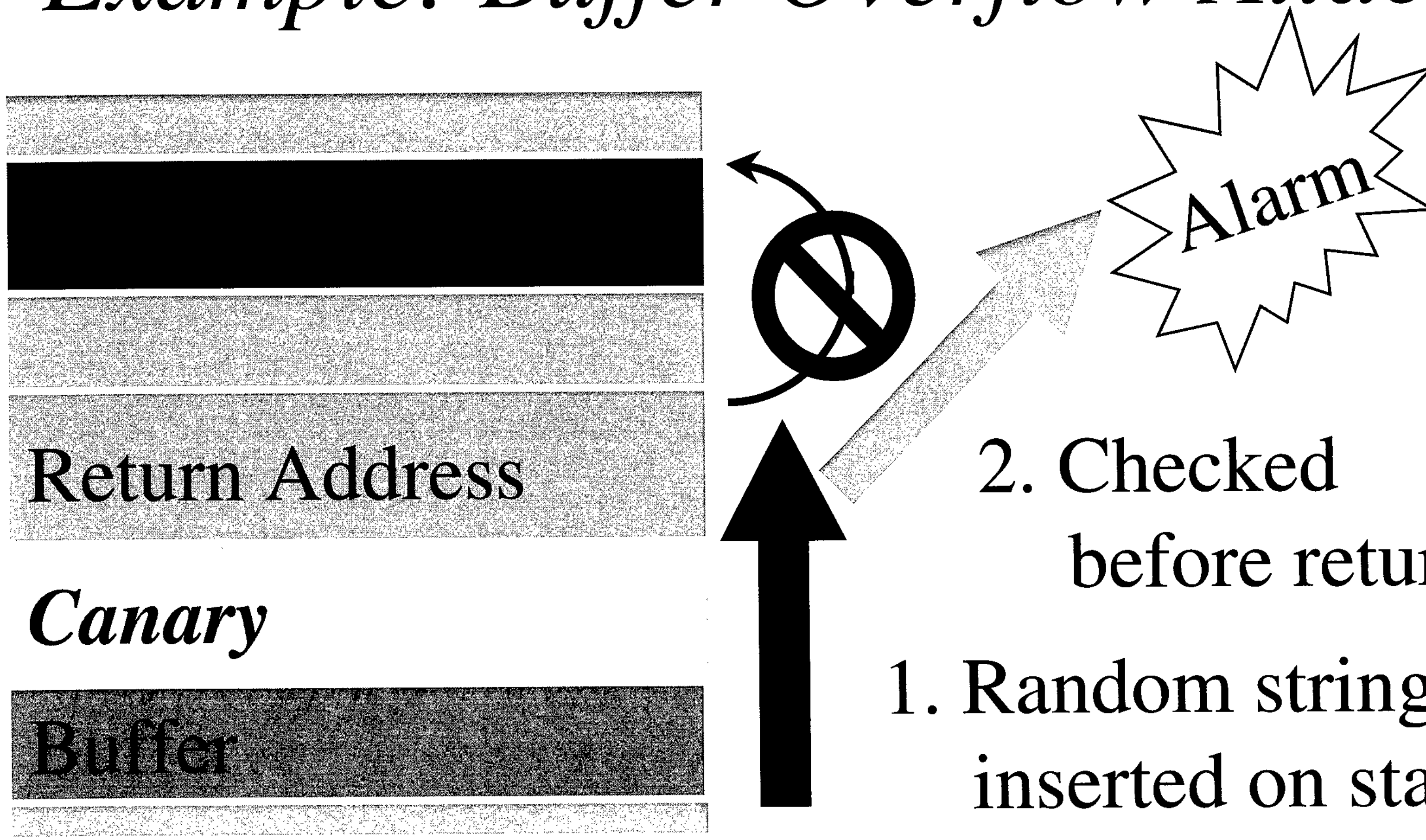
- Imprecision
- Completeness
- Latency

Ideas

- Active interfaces
- Probabilistic methods

Artificial Diversity

Example: Buffer Overflow Attack



2. Checked before return

1. Random string inserted on stack

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Intrusion Tolerant Networks

Maximize residual capacity of network infrastructure following partial compromise

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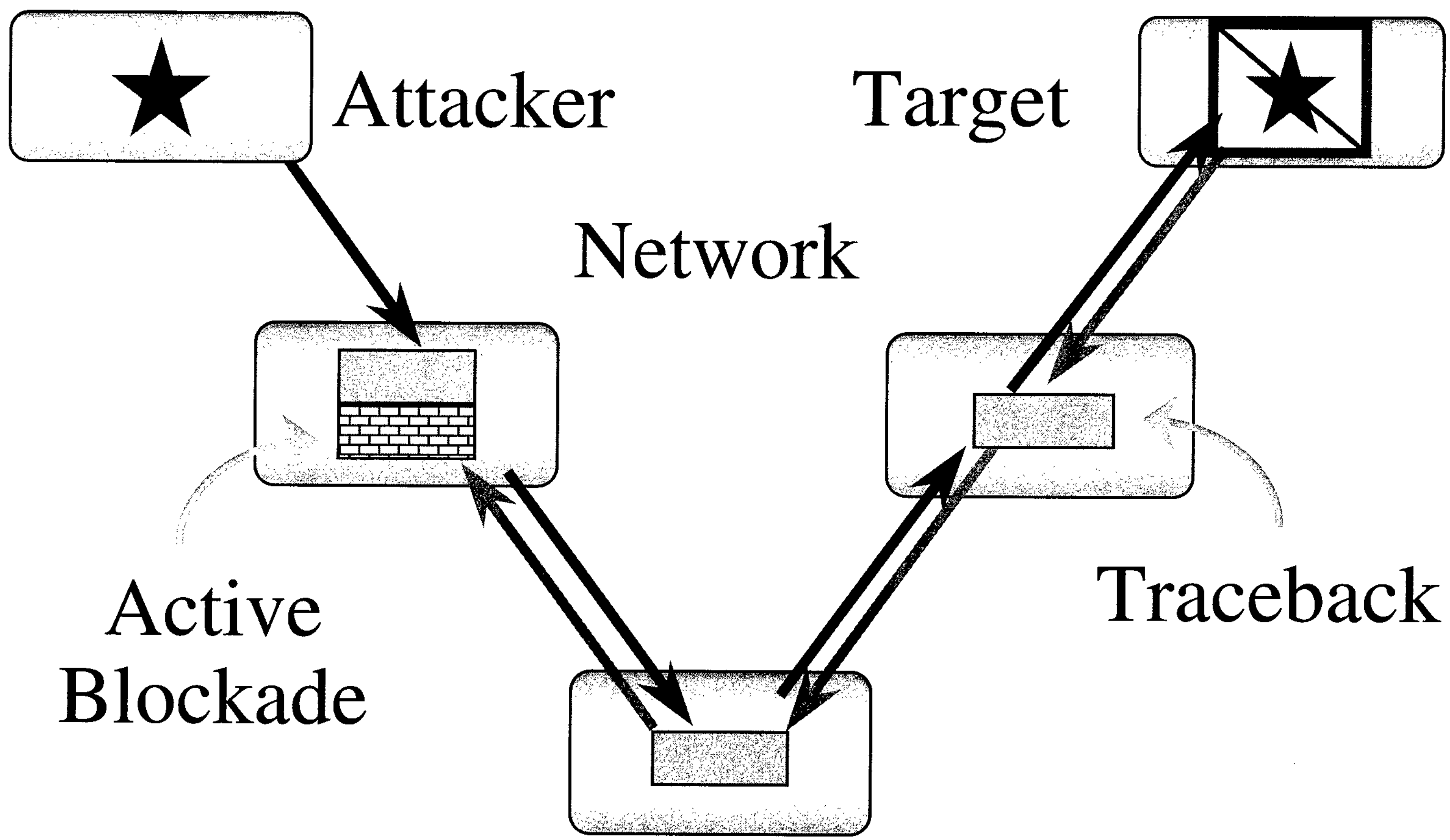
Denying Denial-of-Service

Constrain attacker's resource consumption

- Market-Based Allocation
- Progress-Based Protocols

Active Net Response



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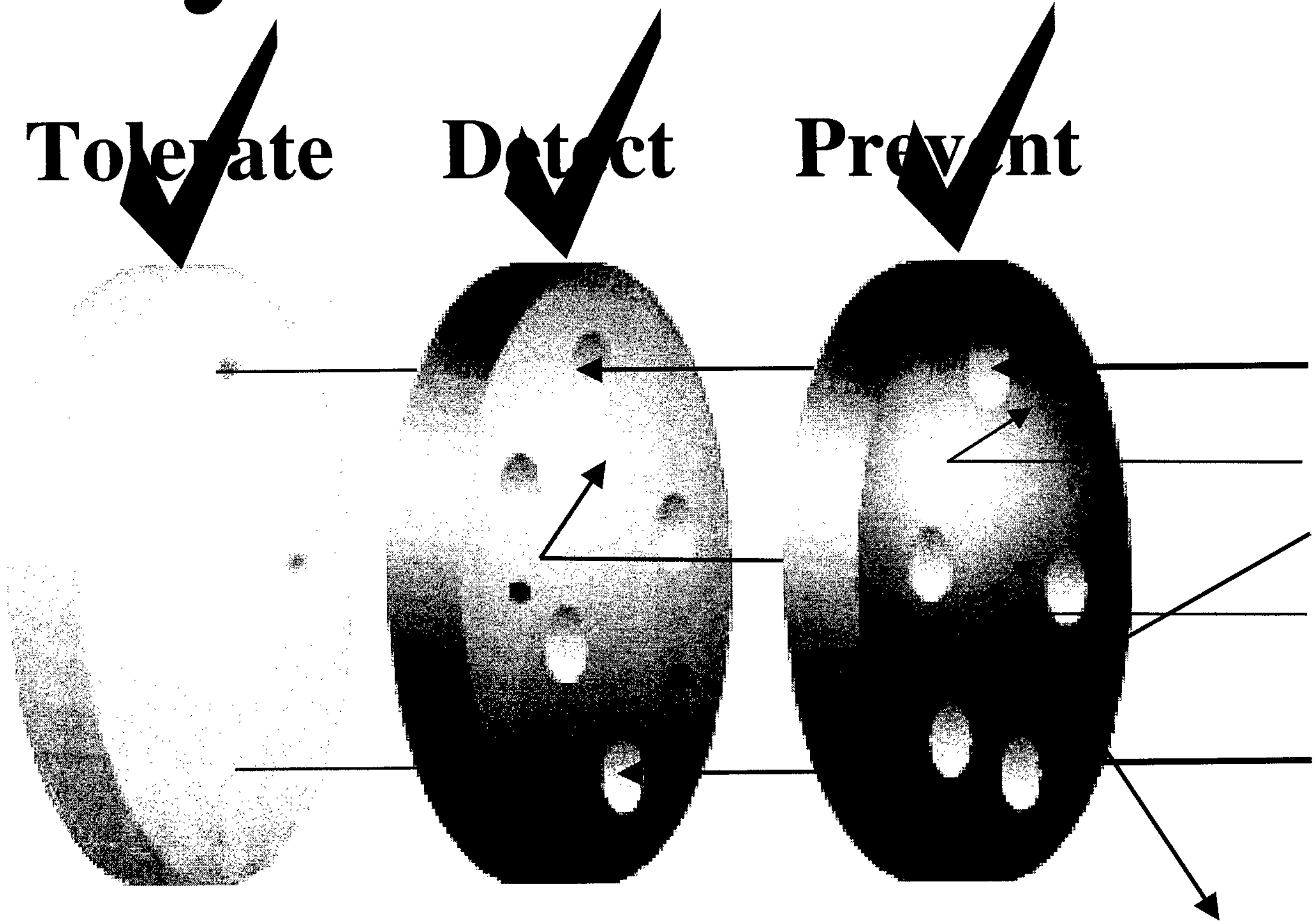
Layered Defense



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TIDES

Translingual Information Detection, Extraction, and Summarization

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Why TIDES?

- 200M Web pages as of 7/97
- 1 M terabytes of audio / year
- Uncounted printed matter
- Foreign language information growing faster than English

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National Security

தலைமைச் செயலகம்
தமிழீழ விடுதலைப் புலிகள்
தமிழீழம்
13.05.1998

எமது தேசிய விடுதலைப் போராட்ட வரலாற்றில் இ
முக்கியத்துவம் வாய்ந்த நாள். எமது எதிரியான சிறீ
மிகப் பெரிய படையெடுப்பான "ஜெயசிக்குறு" இரா
எதிர்த்து நின்று போராடி, இன்றுடன் ஓராண்டு பூர்த்
மாத காலத்திற்குள் முடிந்துவிடுமென போர்ப்பறை
பிரச்சார எடுப்புடன் ஆரம்பமான இப்போர் நடவடிக்
வருடமாகியும் இன்னும் முடிவுபெறாது இழுபடுகிறது.
எட்டிவிட்ட ஒரு தனிச்சமர் என்ற ரீதியில், தமிழீழப்
வரலாற்றில் மட்டுமின்றி உலகப் போரியல் வரலாற்
நீண்டதொரு சமராக இது முக்கியத்துவம் பெறுகிறது
படையெடுப்பை மூர்க்கமாக எதிர்த்துப் போராடி, எதி
நகர்வு வேகத்தை தடுத்து நிறுத்தி, எதிரிப்படைகளை வன்னிக்
காட்டிற்குள் முடக்கி வைத்து உலக இராணுவ வரலாற்றில் ஒரு ஒப்பற்ற
சாதனையை எமது விடுதலை இயக்கம் நிலைநாட்டியிக்கிறது.

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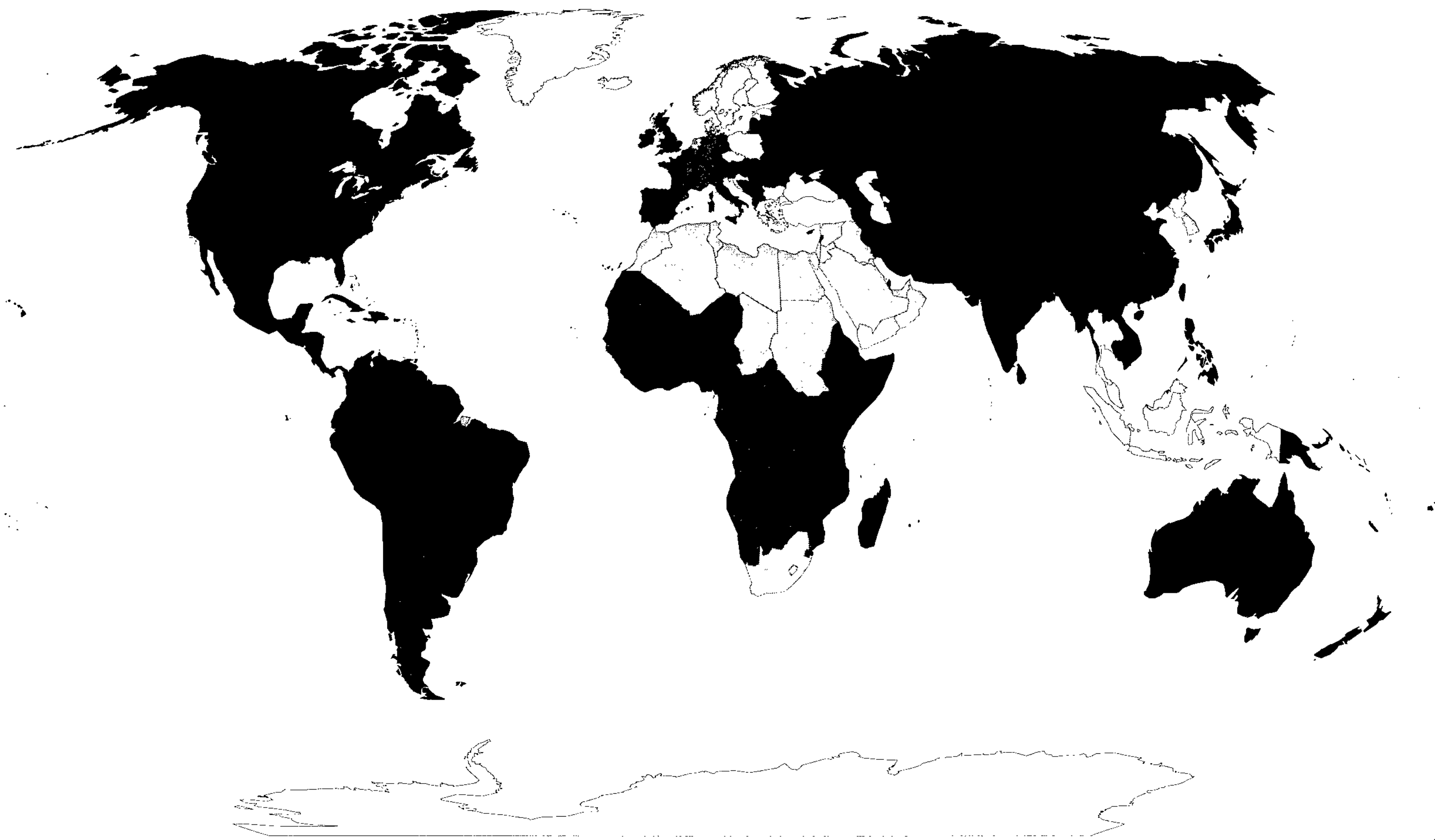
TIDES Goal

- Find and Interpret Information Vital to National Security
  - –Retrieve unfamiliar languages
  - –Translate into English
  - –Extract and correlate content

ITO

DARPA

Machine Translation



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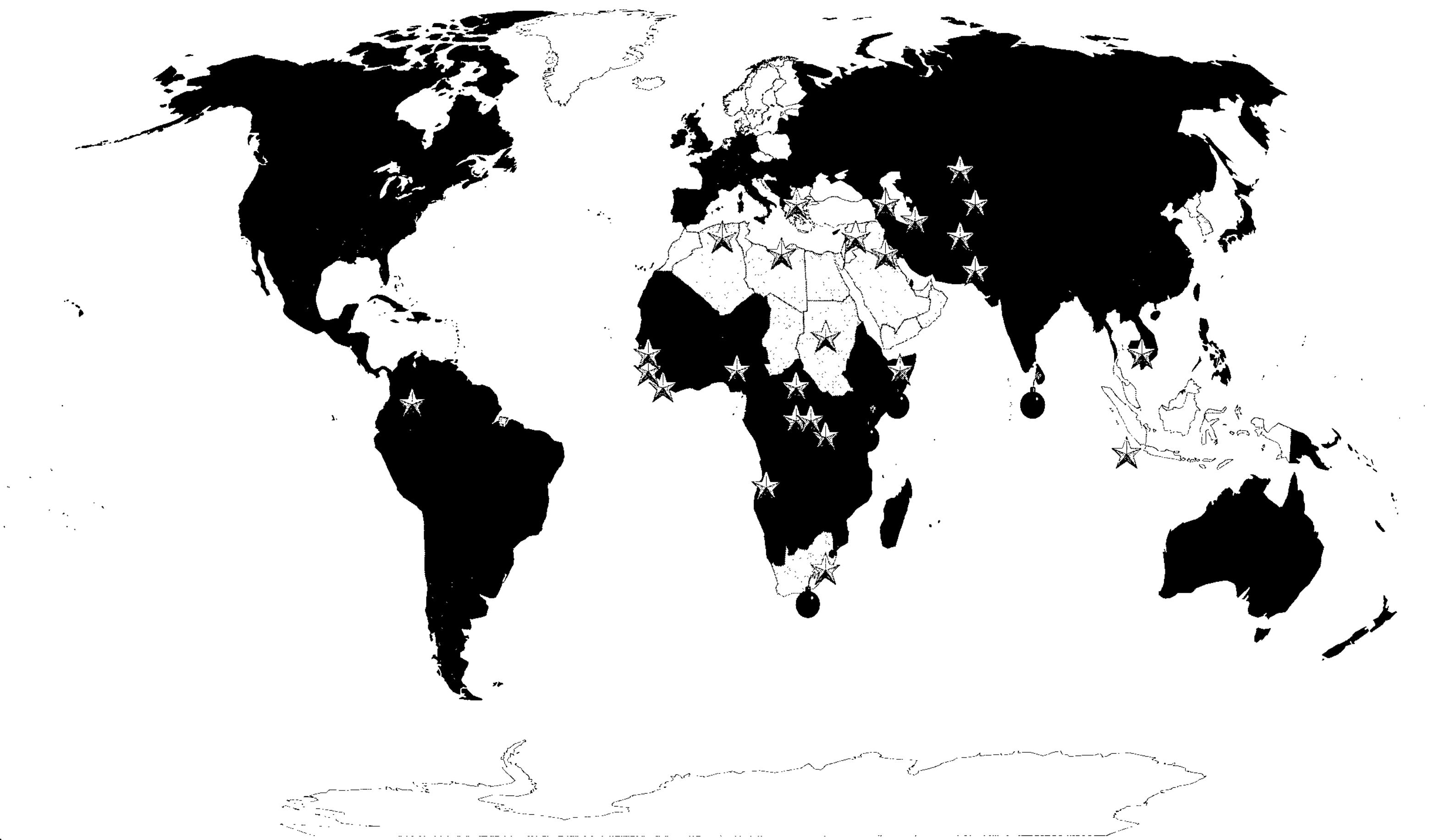
Bombs & Warnings



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Targets

- Translingual access rivaling monolingual access
- Rapid development of MT for new languages
- Multi-document information extraction and correlation

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The Problem

- Key facts, events, relationships
- Most information in text
- Unfamiliar languages
- Inadequate machine translation

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The World - 1999

- ~228 Countries
- >6,700 Languages
- >39,000 Language, dialect, and alternate names

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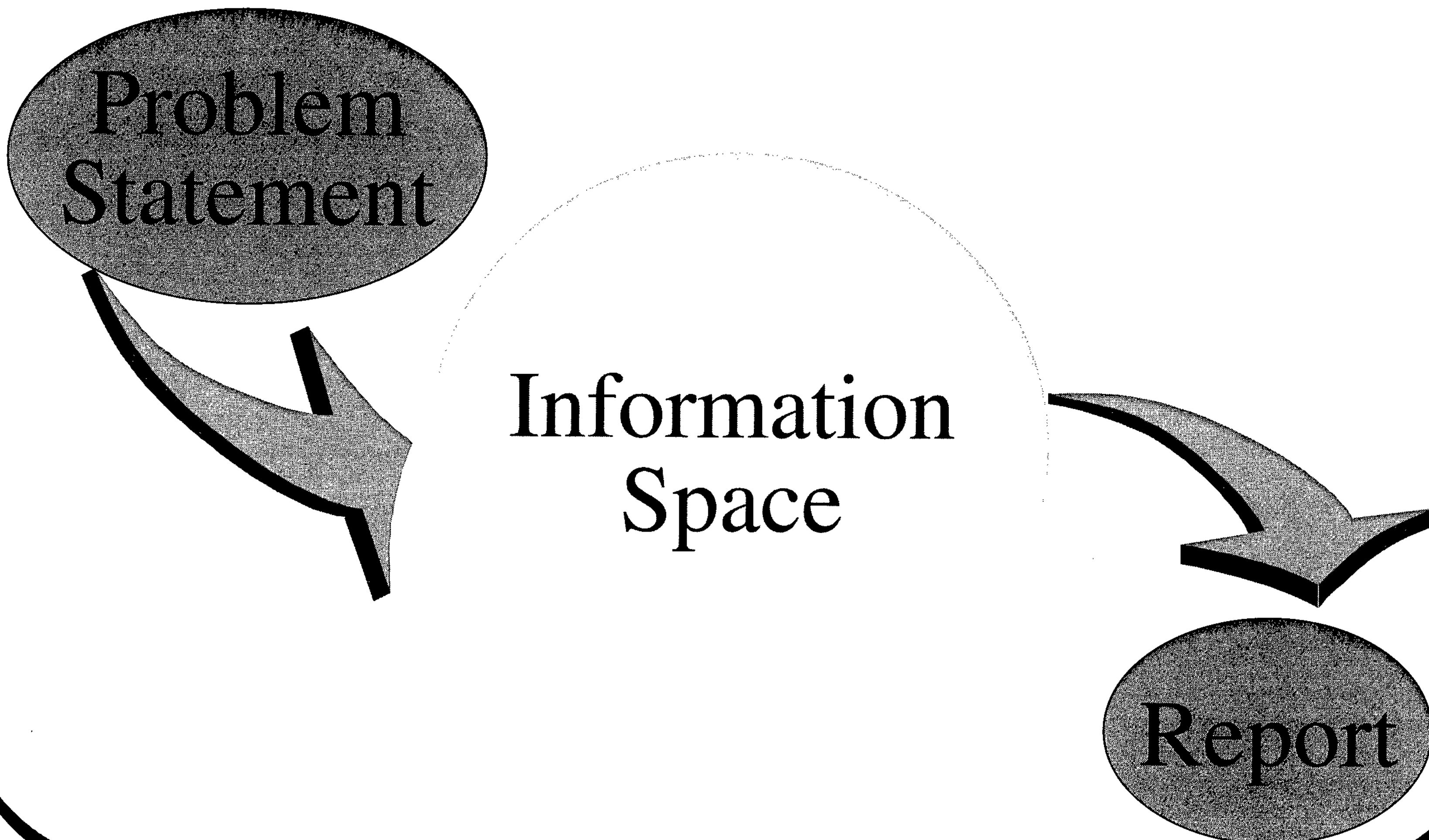
Framework



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Process Steps

- Information Retrieval
- Topic Detection
- Entity Extraction
- Summarization

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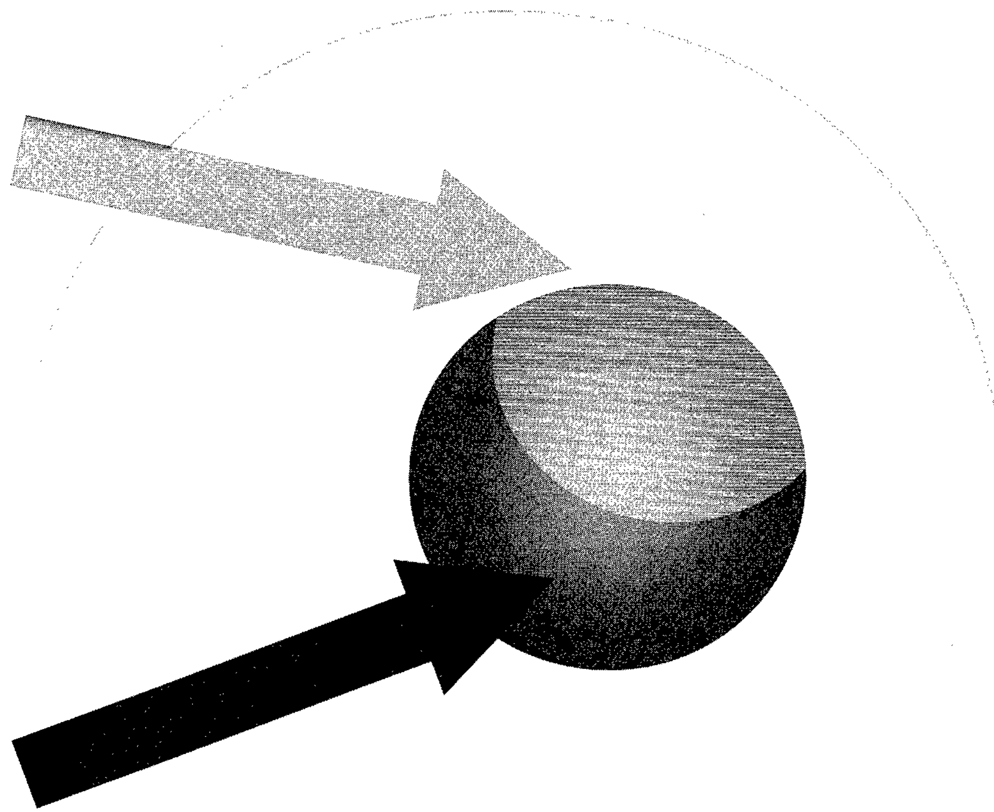
Information Retrieval



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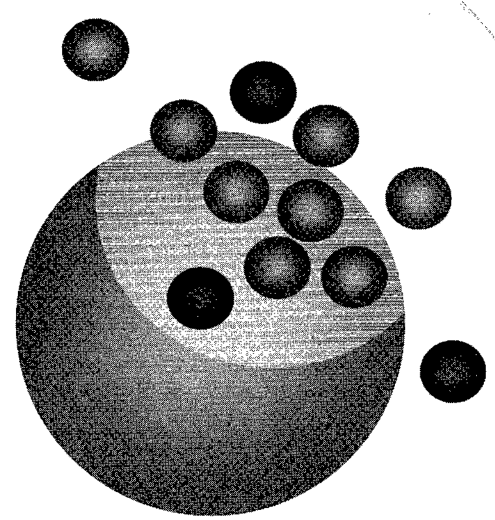
Topic Detection

- Segmentation
- Recognition
- Tracking



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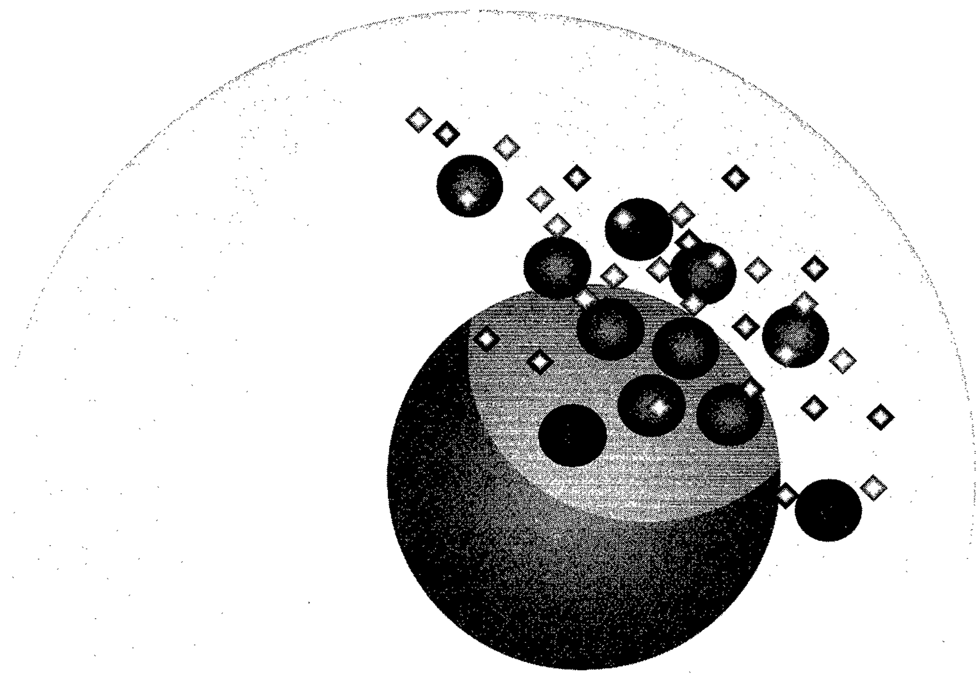
Entity Extraction

- Names
- Places
- Events

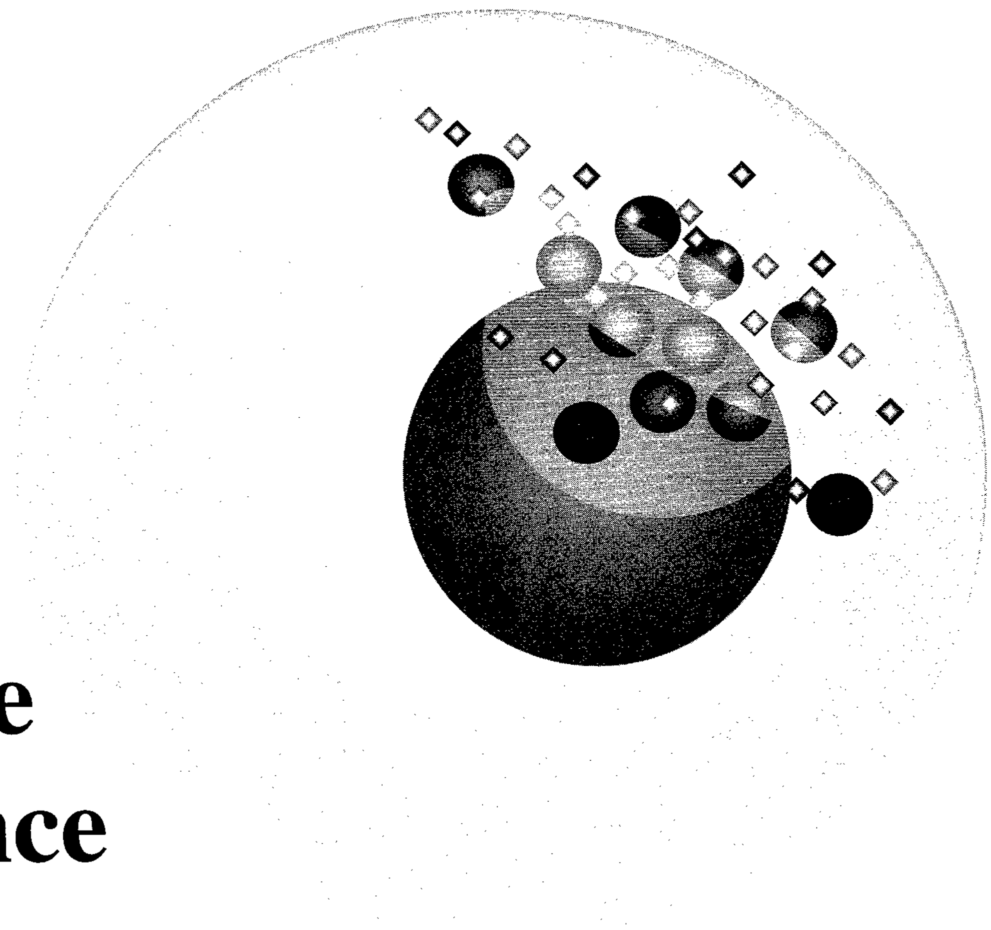


ITO

DARPA

Summarization

- Type
- Content
- Perspective
- Performance



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Environment

- Large information space
- Human knowledge, patience, and labor
- Monolingual (English)

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Beyond English

- Query translation
- Document translation
- 50% performance of monolingual retrieval

ITO

Exploiting Feedback

- Query refinement
- Topic unification
- Content threading
- Multidocument summarization

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TIDES Tasks

- Machine Translation
  - Query
  - Query Refinement
  - Document Understanding

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TIDES Tasks

- Feedback Exploitation
  - Topic Unification
  - Content Threading
  - Summarization

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TIDES Evaluations

- Machine Translation
- Translingual Info Retrieval
- Topic Detection and Tracking
- Document Understanding
- Summarization & Integration

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3-Year Goals

- Improved translingual IR
- Rapid shift to new language
- Multilingual topic recognition
- Multidocument summarization

ITO

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5-Year Goals

- 30+ languages
- Multilingual entity correlation
- Multilingual templates
- Multilingual summarization

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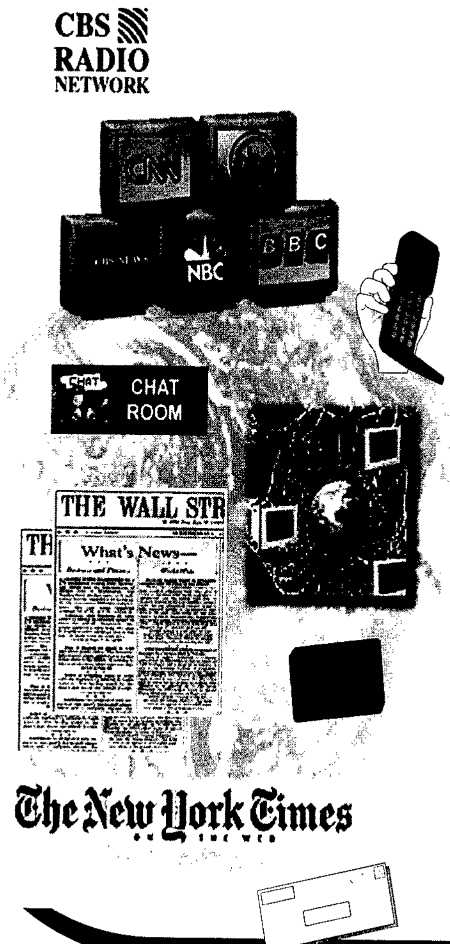
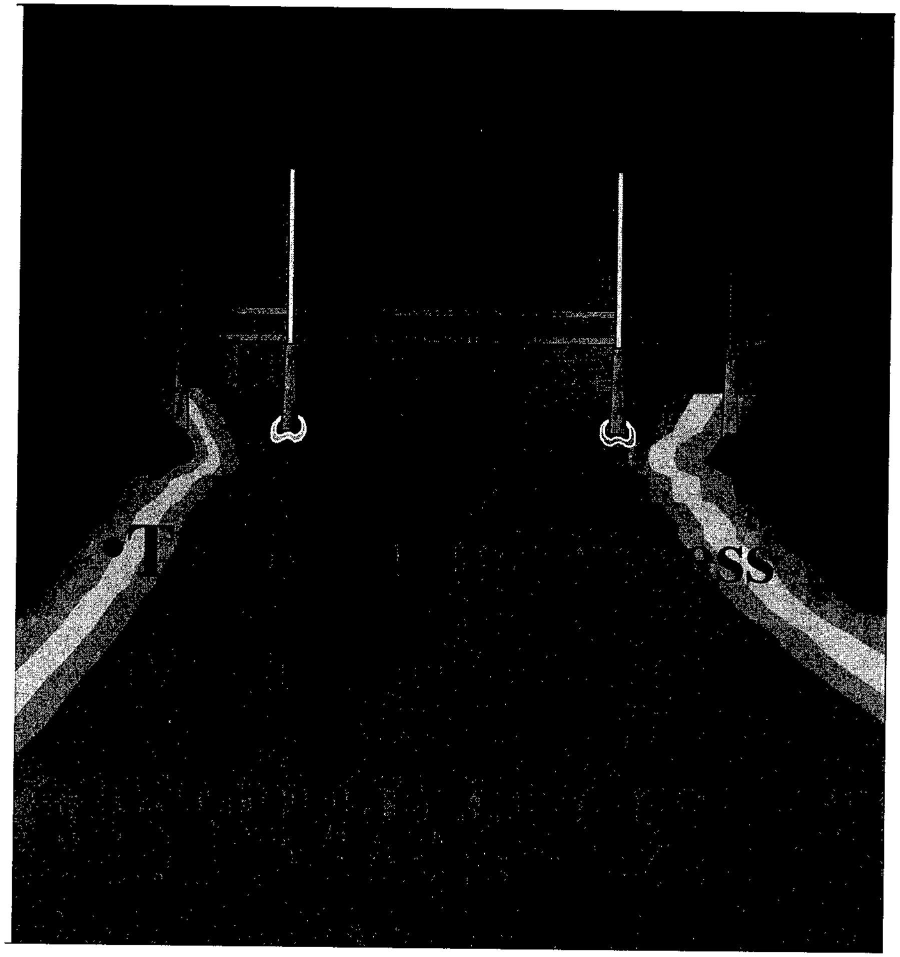
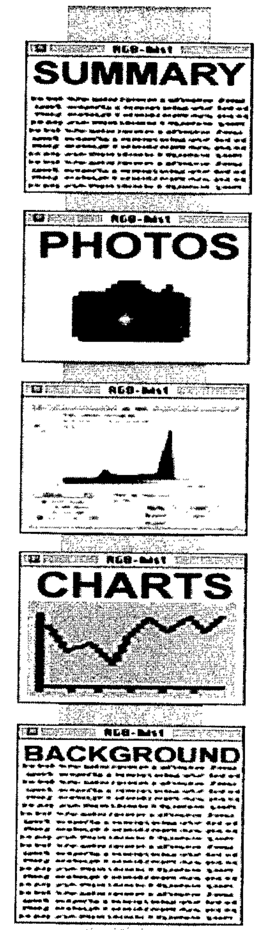
TIDES







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Software-Enabled Control (SEC)

Dr. Helen Gill
Information Technology Office

ITO

DARPA

Current State of Control Technology

- Conservative, limited in capability.
- Human operators "close the loop" for extreme disturbances and high performance.
- Old computational assumptions
  - Limited Resources
  - Fixed, static designs and schedules
  - Loose integration of supervisory and "inner loop" control
  - Limited prediction

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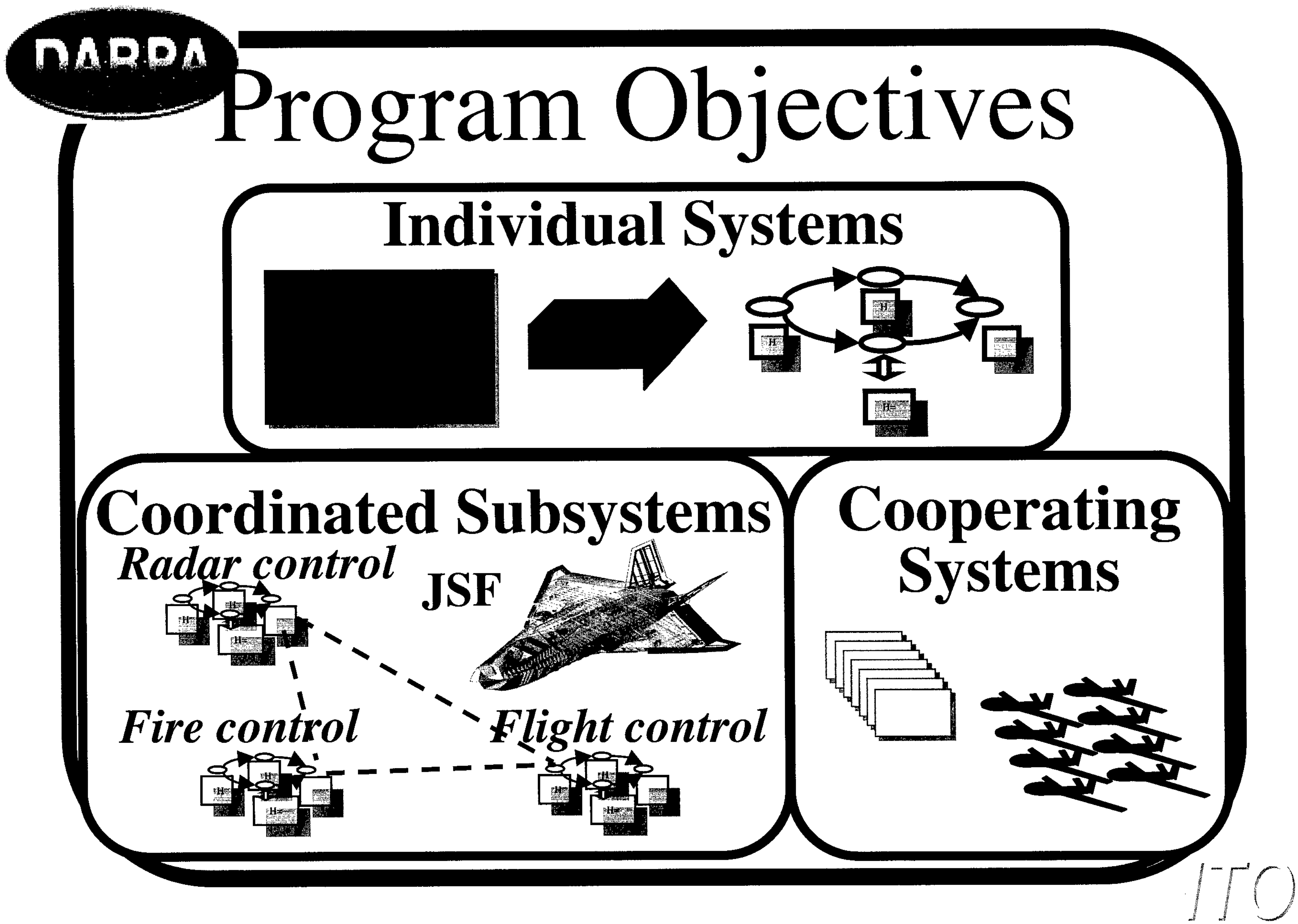
DARPA
Program Objectives
Individual Systems
Coordinated Subsystems
Radar control
JSF
Fire control
Flight control
Cooperating Systems
ITO

DARPA

Program Approach

"Superhuman" Control

- Expand operational envelopes of vehicles through improved control systems.
- Leverage rapid increases in processing power and storage capacity.
- Use dynamic information to dramatically improve control and coordination.

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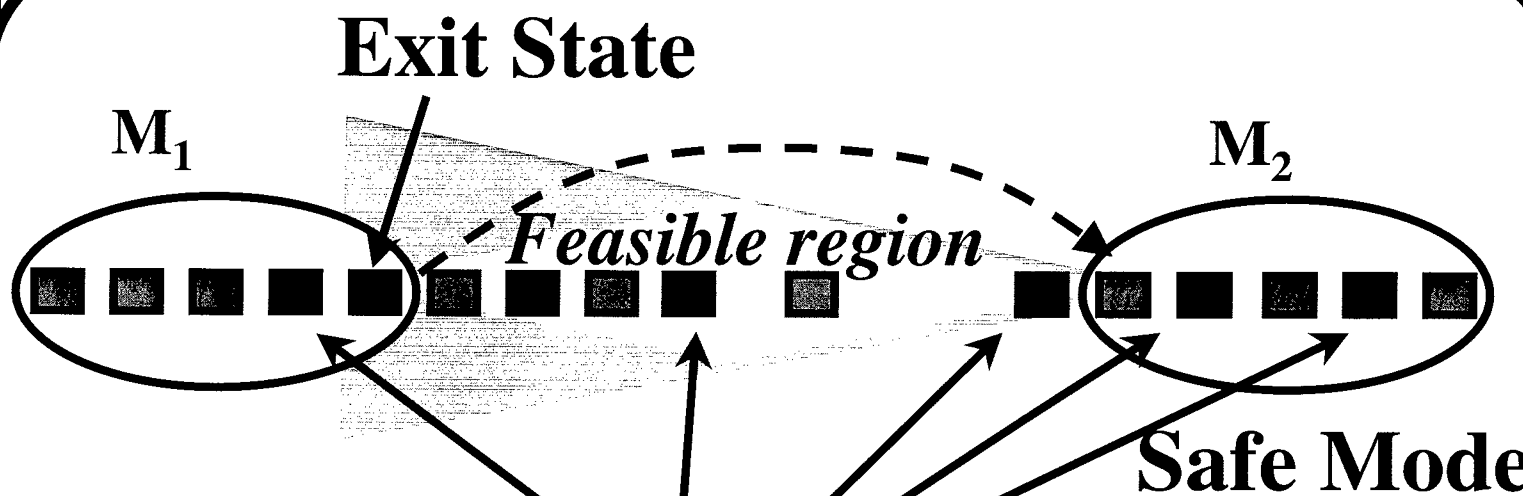
Technical Tasks

- Active State Models
- Coordinated Multi-Modal Control
- On-Line Control Customization
- Open Control Platform

ITO

Active State Models

...With Predictive Transitions



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Active State Models

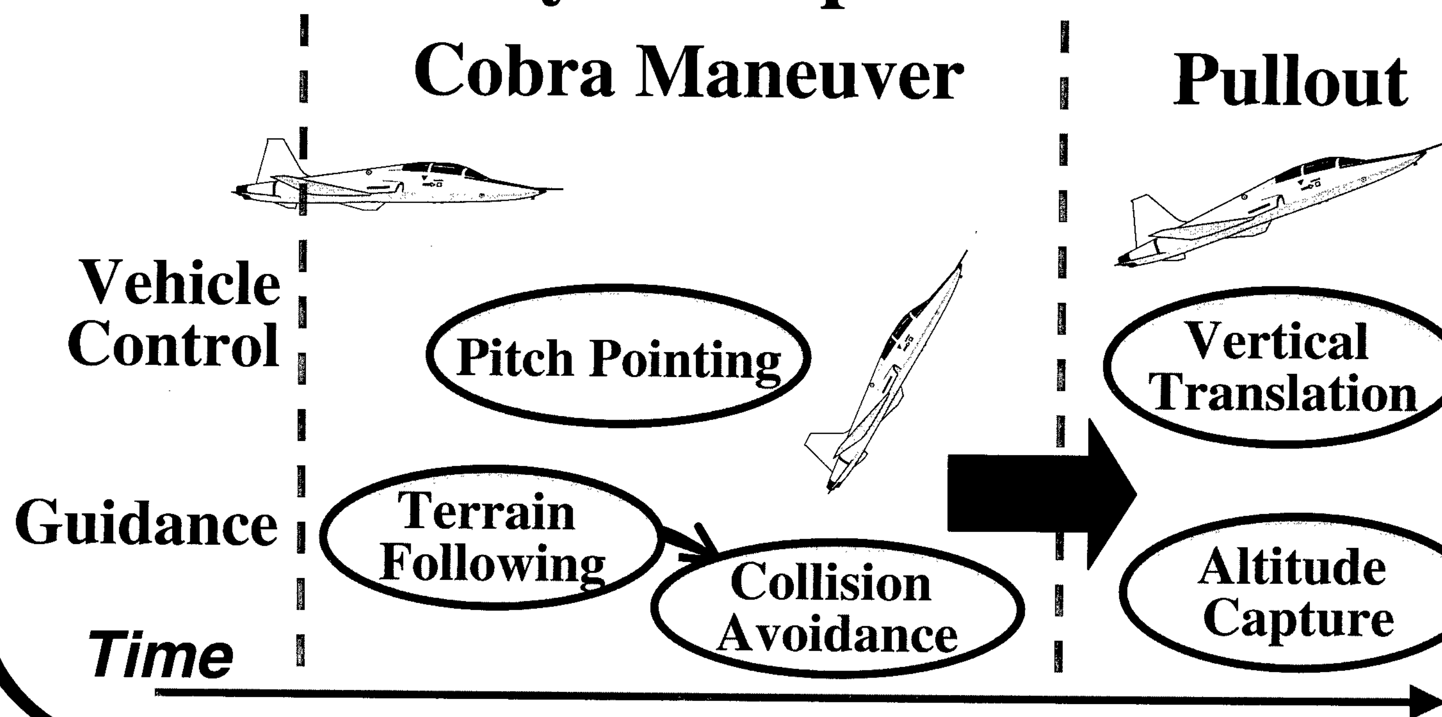
Challenges

- Dynamically exploit first-principles knowledge and on-line data to improve robustness.
- Accommodate multiple system and environmental factors.
- Predict effects over very large state and mode spaces.
- Rapidly assess damage, change.

ITO

Coordinated Multi-Modal Control

Problem: Dynamic coordination of subsystem operation



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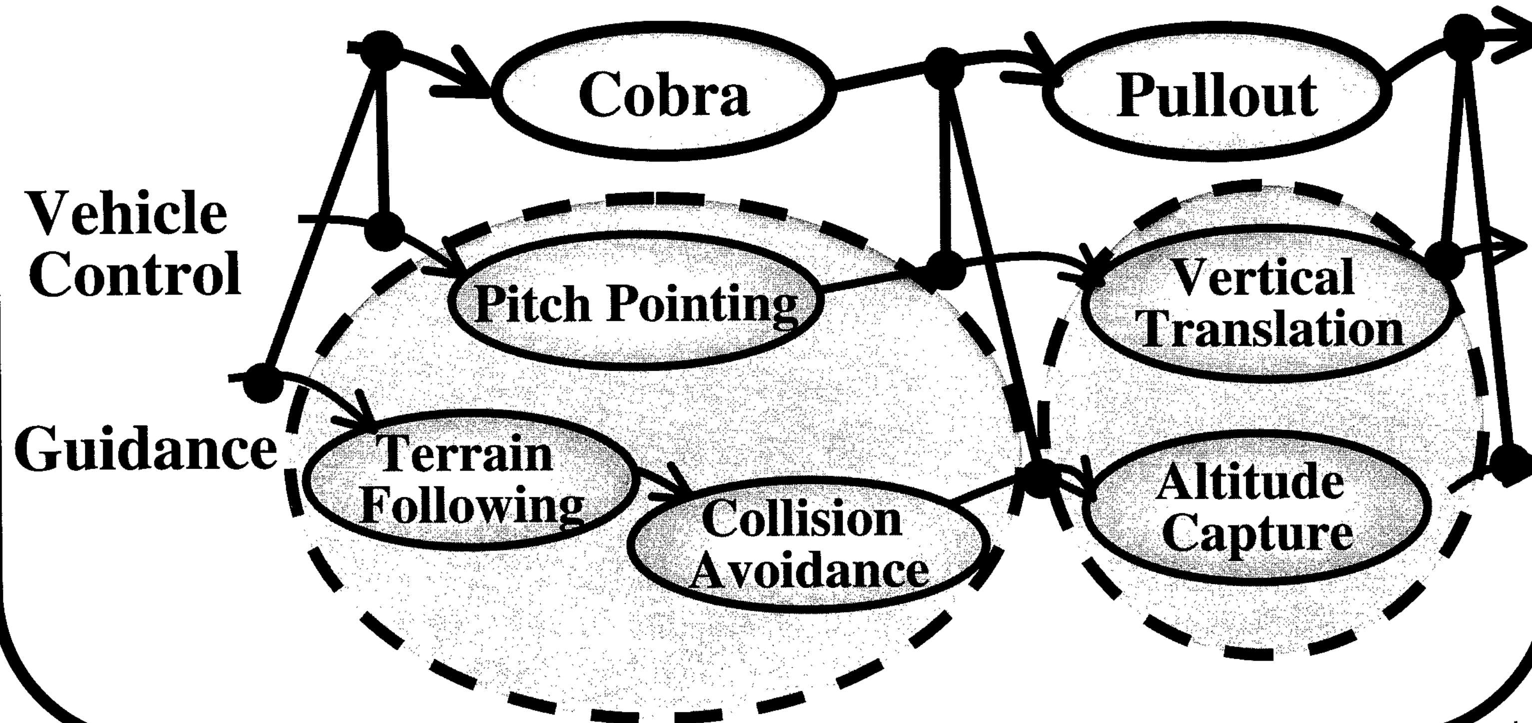
Coordinated Multi-Modal Control

Coordination and Deconfliction of Control



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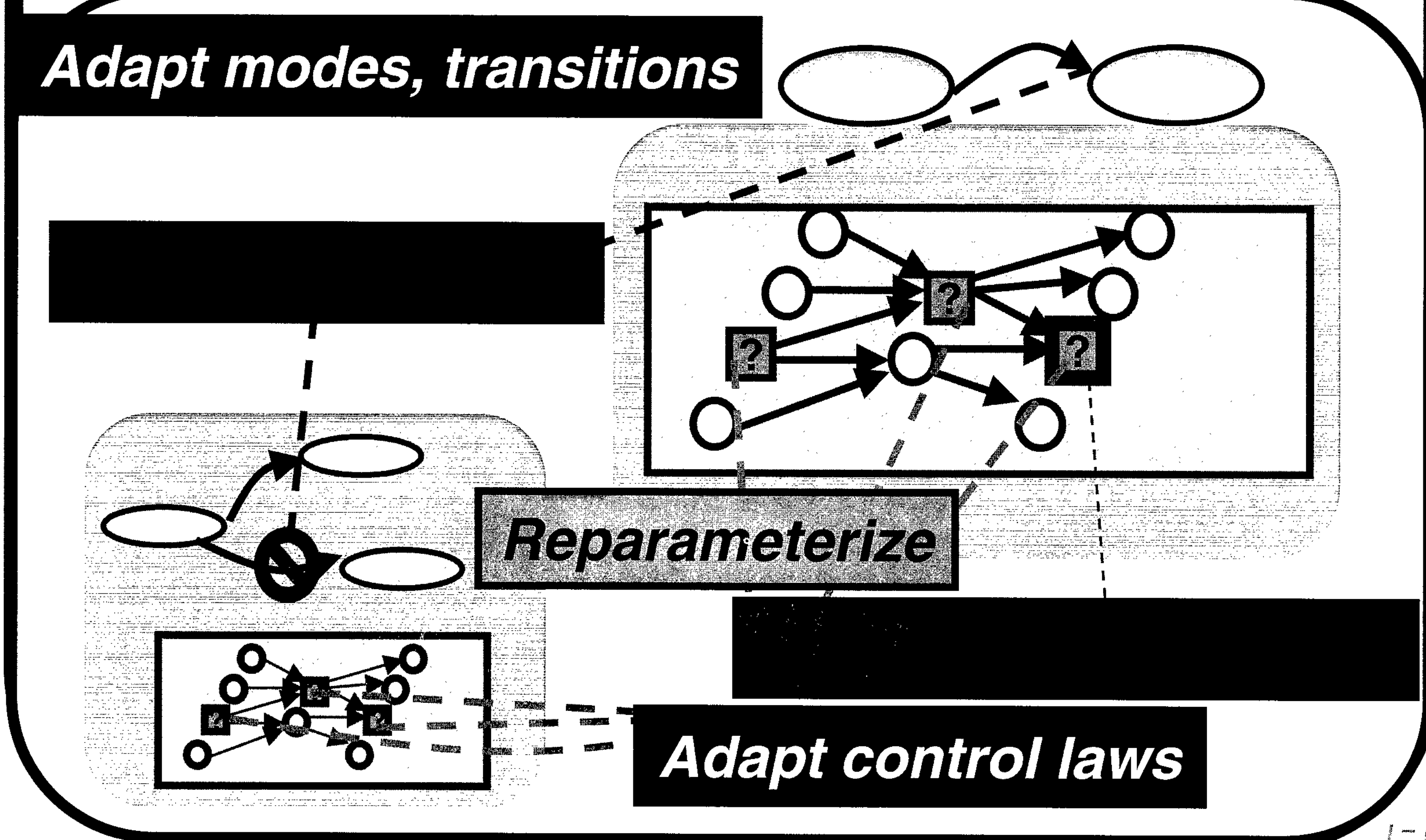
Coordinated Multi-Modal Control

Challenges

- Provide coordinated operation.
- Preserve stability of individual systems, as well as global stability and performance.
- Provide efficient control coordination.
- Enable distributed implementation for physically and geographically separated components.

ITO

On-Line Control Customization



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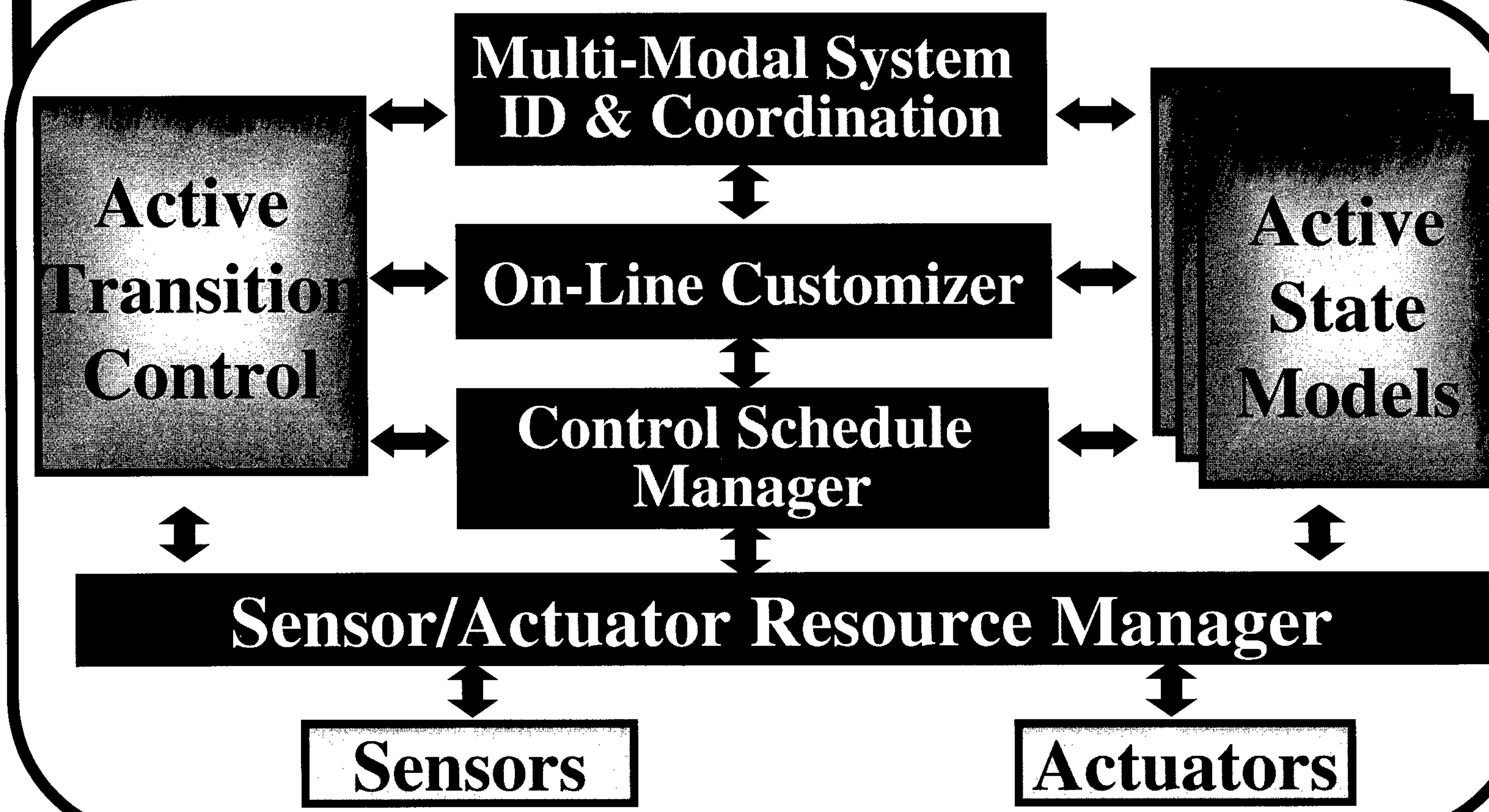
On-Line Control Customization

Challenges

- Control re-parameterization and reconfiguration during operation, that:
  - Accommodates dynamically occurring coordination requirements
  - Accommodates environmental disturbances and damage
  - Accommodates sensors and actuators that vary dynamically in effectiveness
  - Preserves stability

ITO

Open Control Platform



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Open Control Platform

- Provide control "middleware" and tool support for building commodity controllers.
- Provide parametric and structural framework to support SEC active-model-based, coordinated, and adaptive multi-modal control technologies.
- Provide flexible experimental platform for SEC control research and demonstration.

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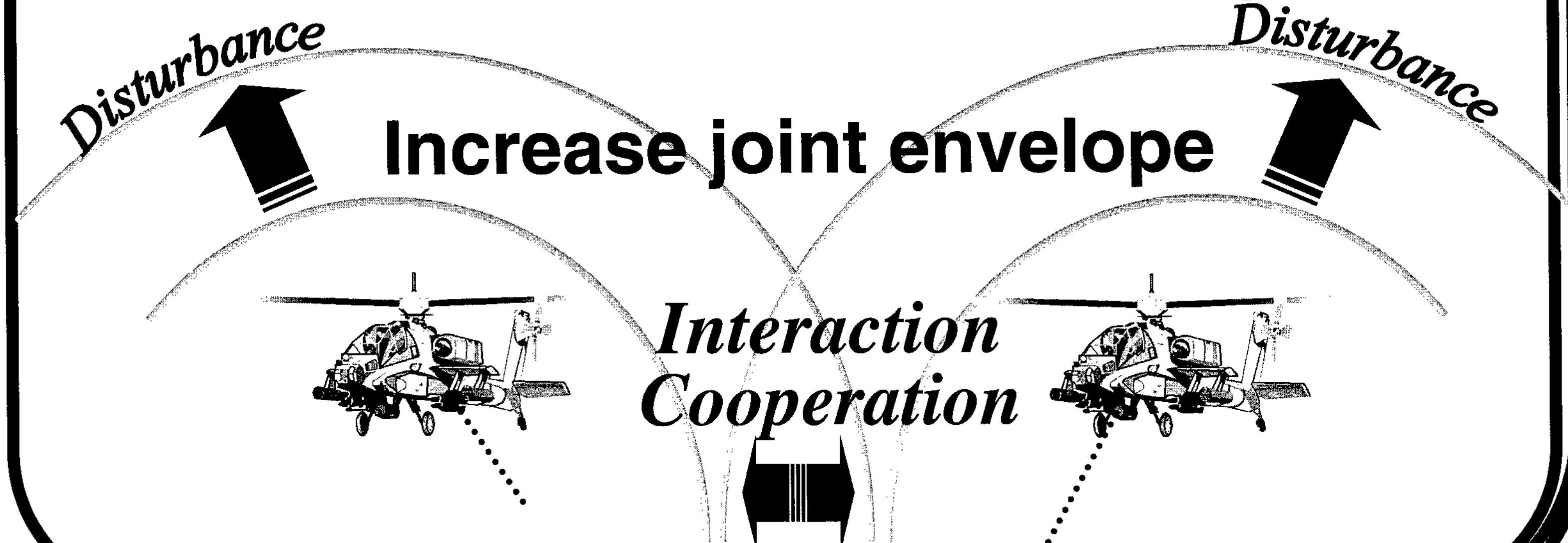
Experiment

Cooperative airlift

Increase controlled envelope

Increase joint envelope



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Demonstration

Goal: Enable high performance autonomous tactical maneuvers for evasion and combat agility.

X-36

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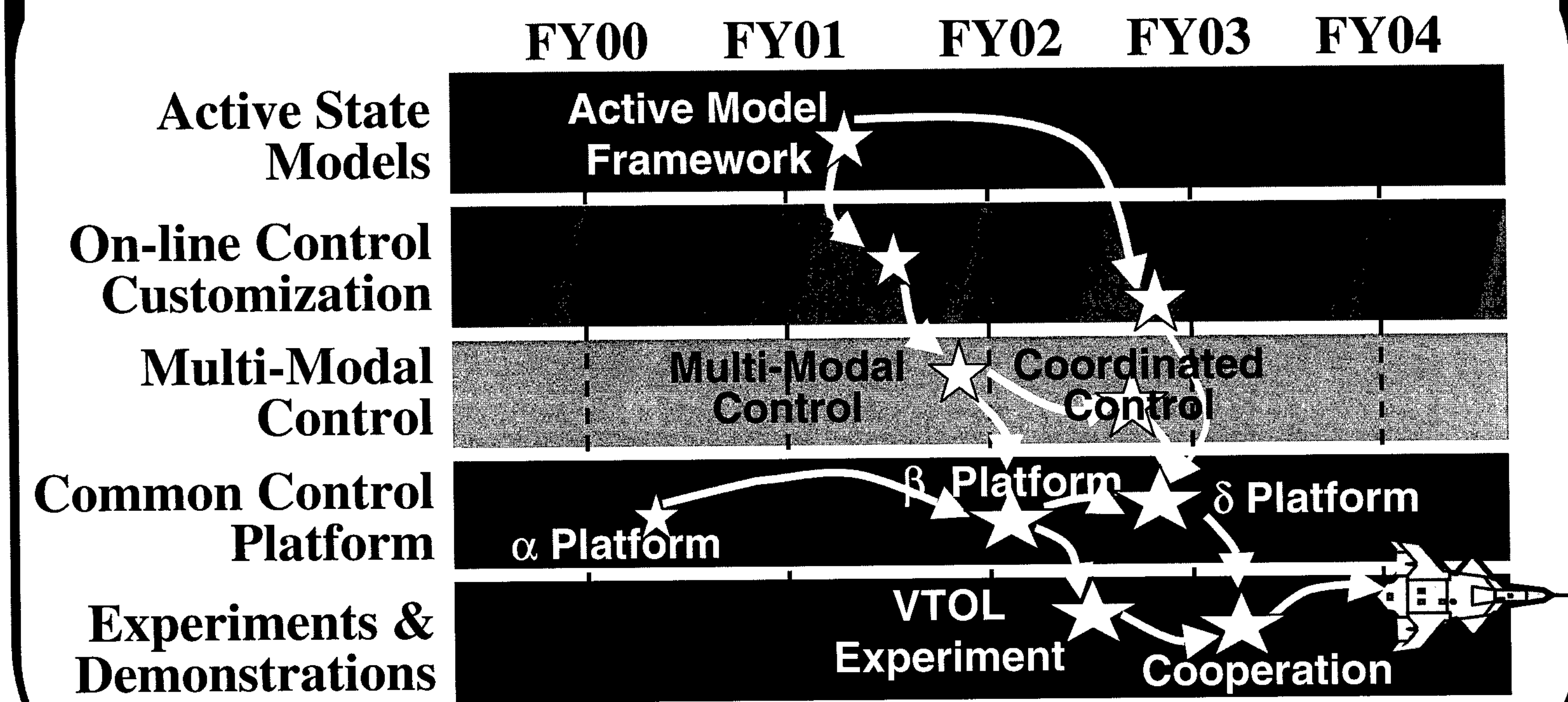
Roadmap



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Impact:

- **Reinvent Control Systems**
- Reusable Control Software
- Open Control Platforms

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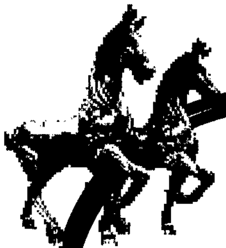
DARPA Bio Futures

Adding the "Bio Dimension" to DARPA Futures

Stephen L. Squires



DARPA

What are we doing?

- ➡ Reflecting on the past
- ➡ Recognizing trends and limits
- ➡ Formulating alternative futures
- ➡ Developing a strategic vision
- ➡ Stimulating strategic processes
- ➡ Moving toward advanced futures

➔Reflecting on the past

- Over 50 years of ***accelerating advance***

...

- The role of
  science,
  technology,
  applications.
- The role of DARPA in the
  national and global
  system context.

DARPA

➡Recognizing trends and limits

- The information technology revolution enabled by microelectronics
- The revolutions in biology with minimal coupling to info and micro
- The increasingly pervasive use of information technology in science, technology, society
- The potential of coupling to biology

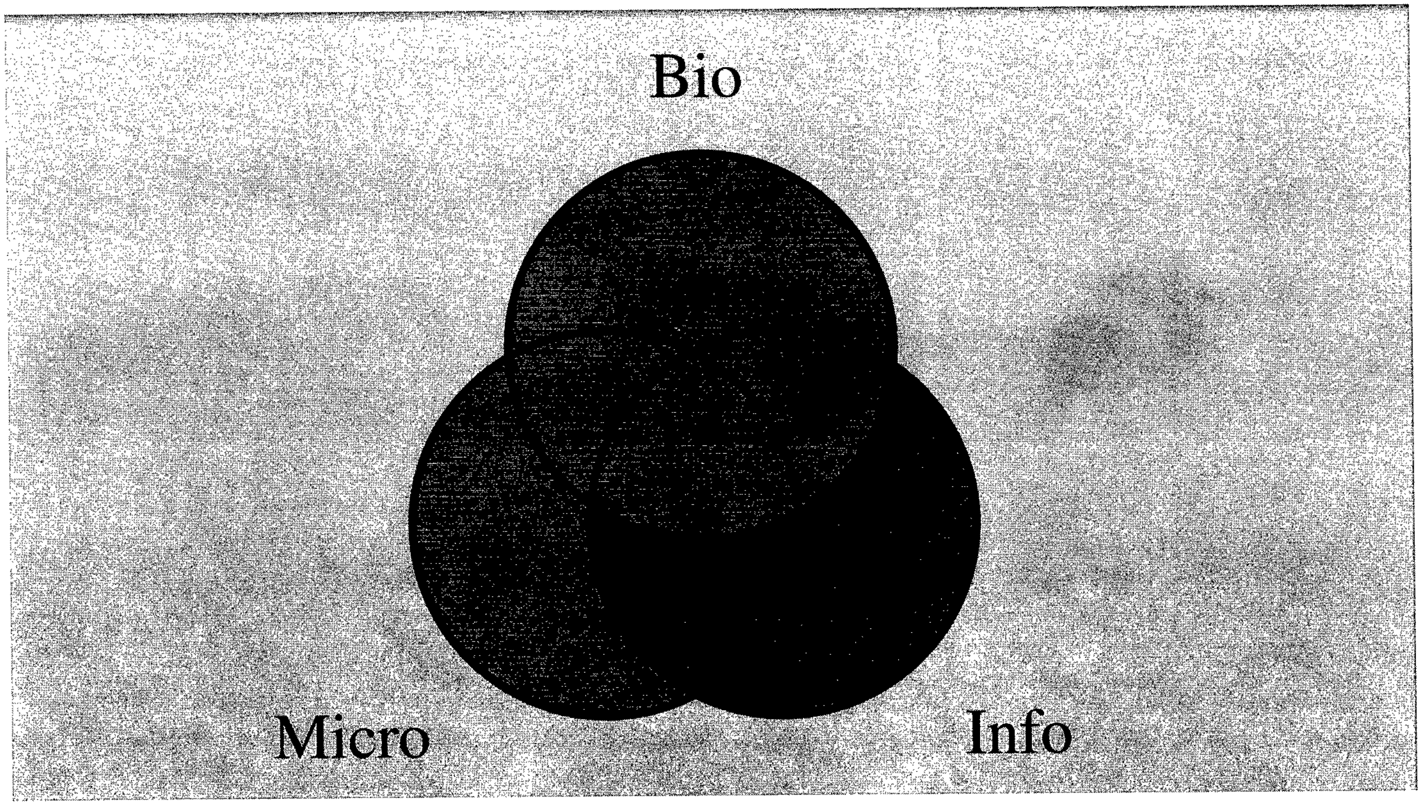
➡Formulating alternative futures

- Recognize the potential of increased coupling among [Bio:Info:Micro]
- Imagine the scientific discovery of fundamental devices at the intersection
- Imagine their transformation to new scalable systems and applications

Why this is important ...

- Defense Challenges
  - Bio Defense
  - Human Interfaces
  - Others?
- DARPA Opportunities
  - Enabling new mission capabilities
  - Stimulating new science and technology
  - Building on DARPA Strengths

Interactions

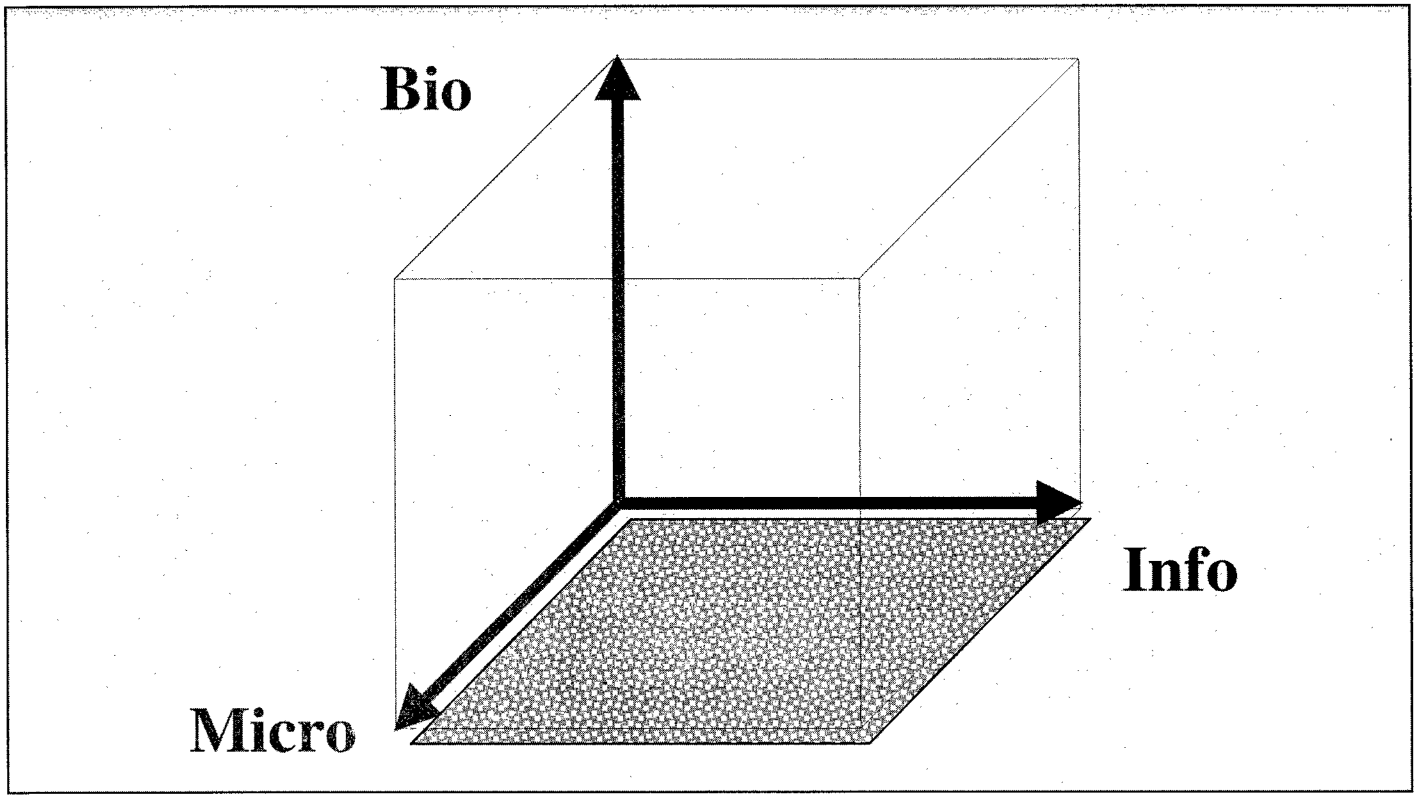


Scale

- 10^{-3} milli
- 10^{-6} micro
- 10^{-9} nano
- 10^{-12} pico
- 10^{-15} femto
- 10^{-18} atto
- … down into sub atomic

- … up toward galactic
- 10^{24} *O(Avogadro)*
- 10^{21}
- 10^{18} E Exa
- 10^{15} P Peta
- 10^{12} T Tera
- 10^{9} G Giga
- 10^{6} M Mega
- 10^{3} K Kilo
- 10^{0} (1)

The [Bio:Info:Micro] Space



Each dimension is Log(scale) with origin at Log(1)

Fundamental Devices

A Generic 21st Century Characterization

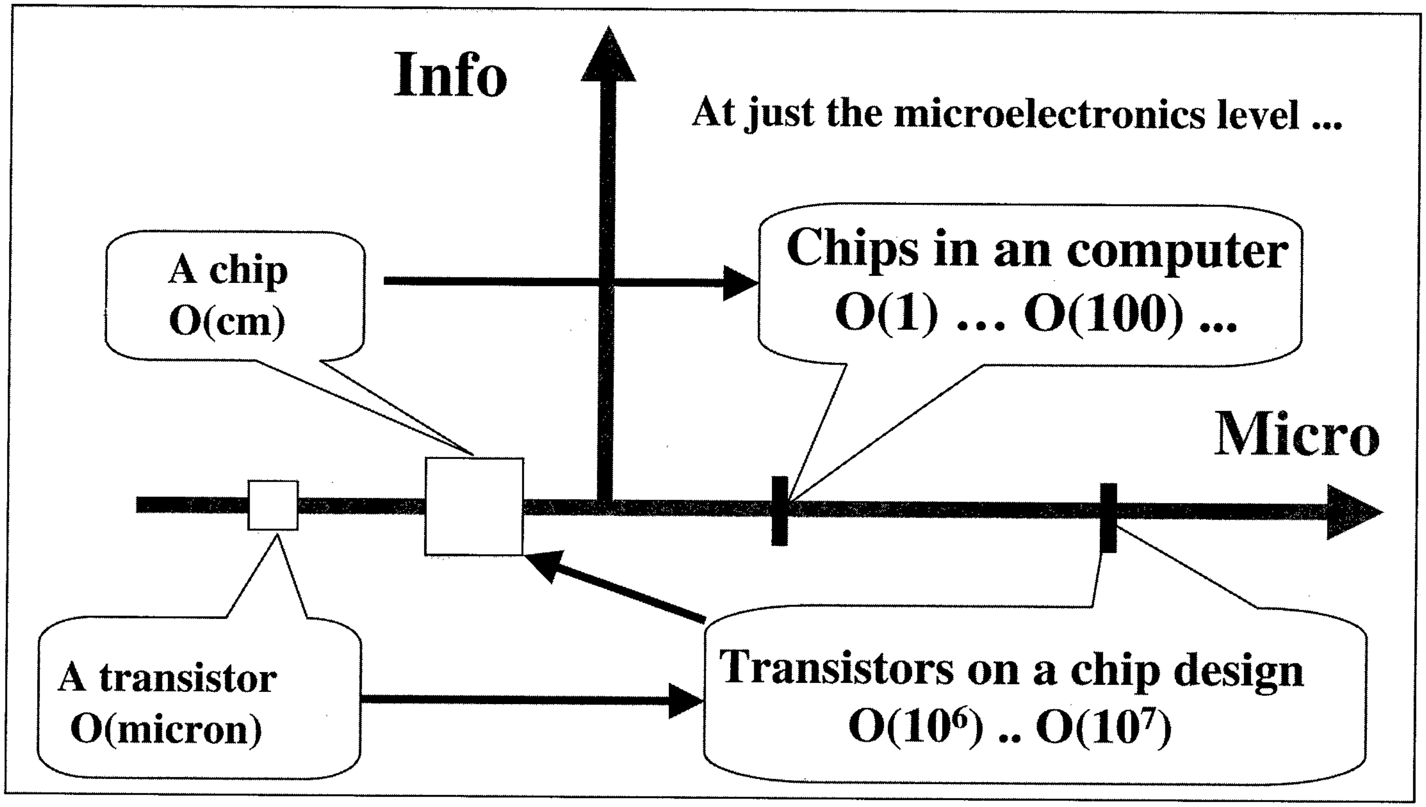
- Enables fundamental advance
- Functional unit of replication
- Scalable production system
- Integrable into systems

The details are different for each kind ...

"Solid State" Technologies enable [Micro:Info]

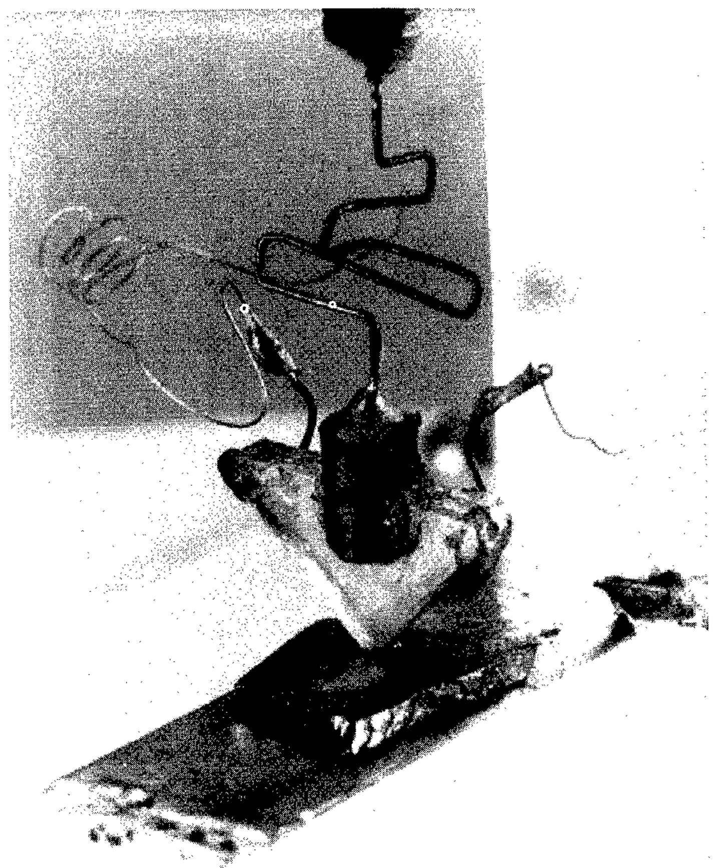
Transistors, Lasers, Displays
and "Magnetics"

[Micro:Info]

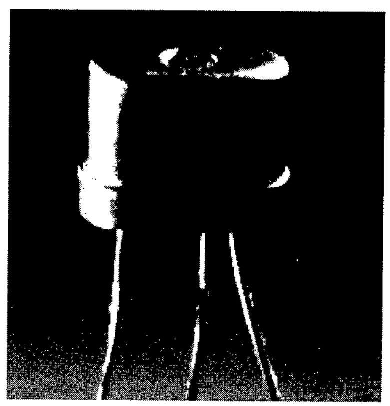


Info
At just the microelectronics level ...
A chip
O(cm)
Chips in an computer
O(1) … O(100) ...
Micro
A transistor
O(micron)
Transistors on a chip design
O(10^6) .. O(10^7)

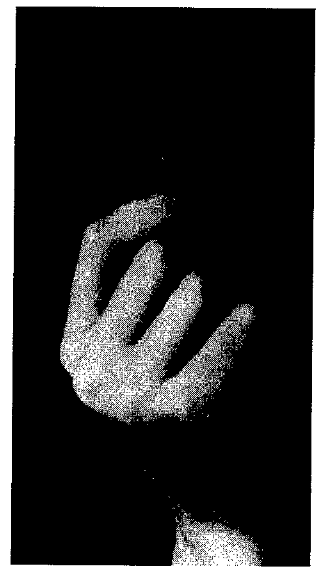
The transistor invention ...



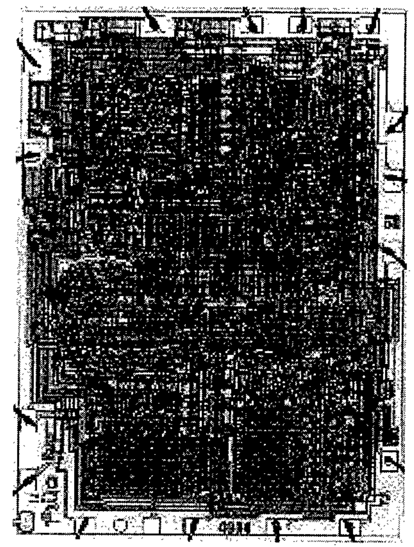
... from Transistors to ...



Transistor
in a Can

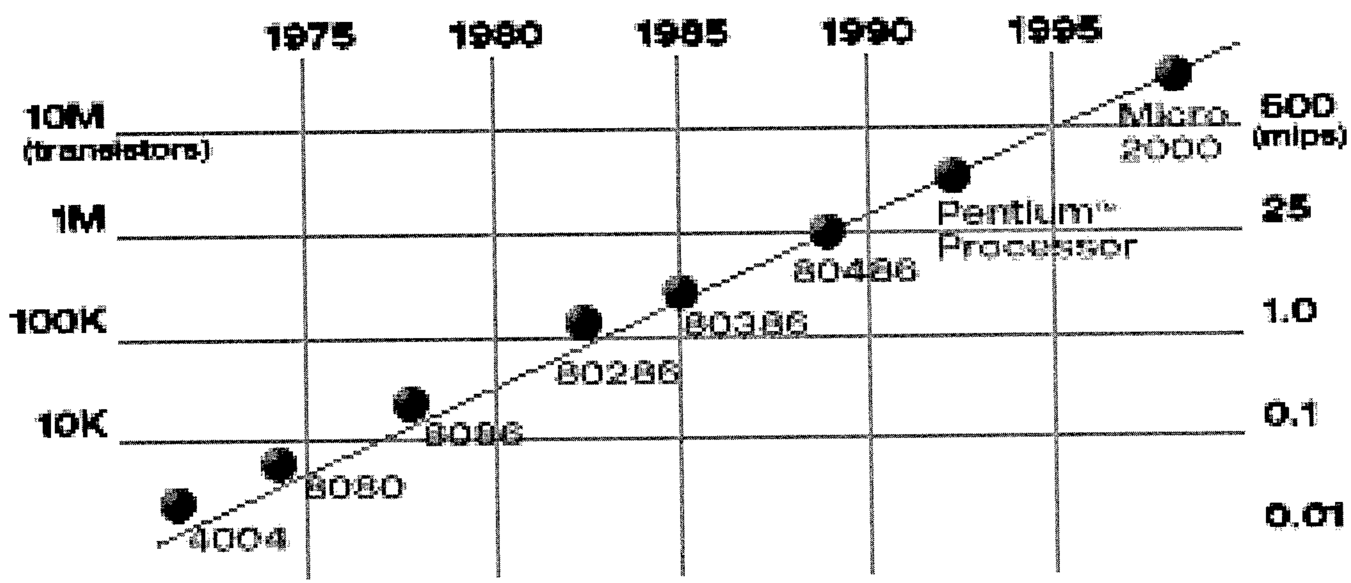


Integrated Circuit
held by tweezers



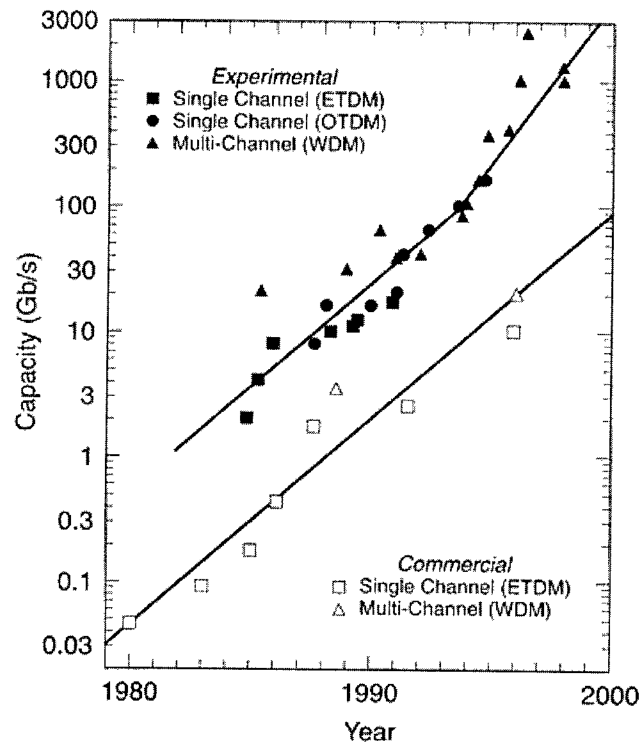
Microprocessor
photomicrograph

Moore's Law



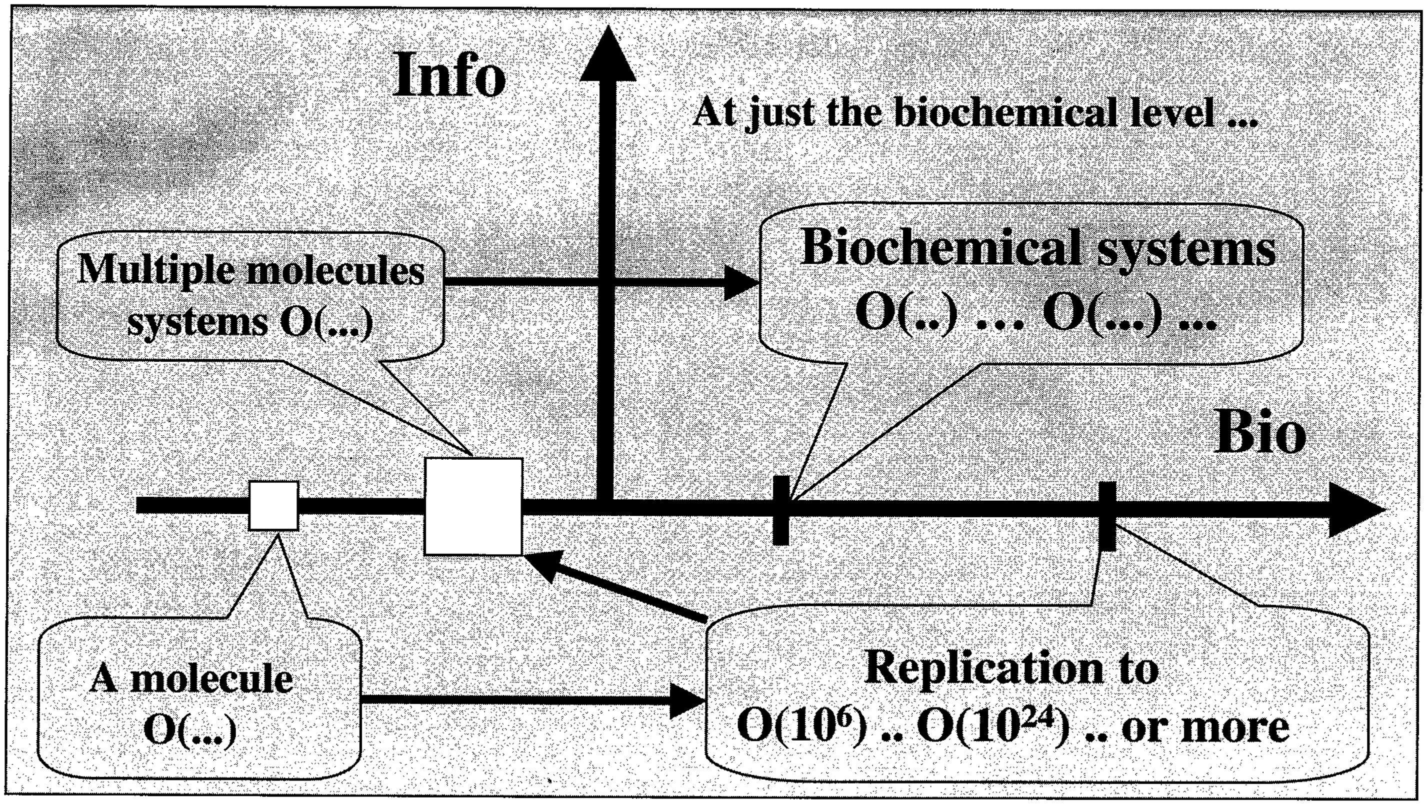
1975
1980
1985
1990
1995
10M
(transistors)
1M
100K
10K
500
(mips)
25
1.0
0.1
0.01
4004
8080
8086
80286
80386
80486
Pentium™
Processor
Micro
2000

Photonics Curves

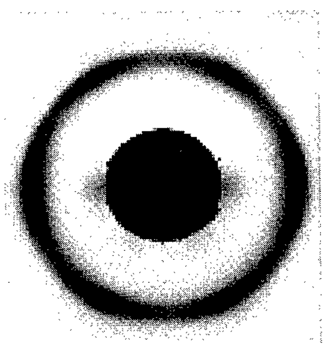


“Bio State” Technologies enable [Bio:Info:Micro]

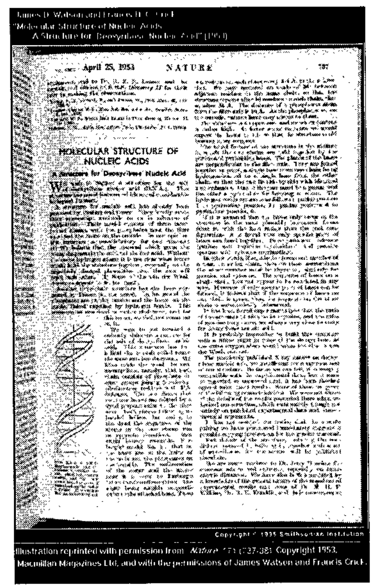
[Bio:Info]


Info
At just the biochemical level ...
Multiple molecules systems O(...)
Biochemical systems O(..) … O(...) ...
Bio
A molecule O(...)
Replication to O(10^6) .. O(10^24) .. or more

The DNA discovery ...



X-ray
crystallography

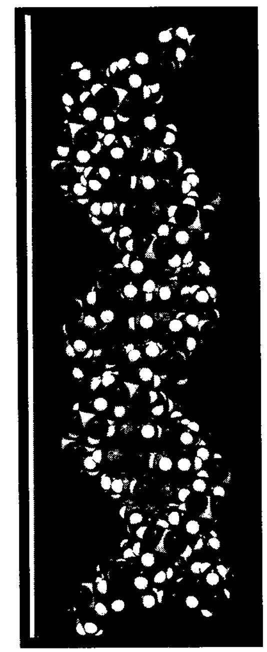


April 25, 1953 NATURE

MOLECULAR STRUCTURE OF NUCLEIC ACIDS

A Structure for Deoxyribose Nucleic Acid

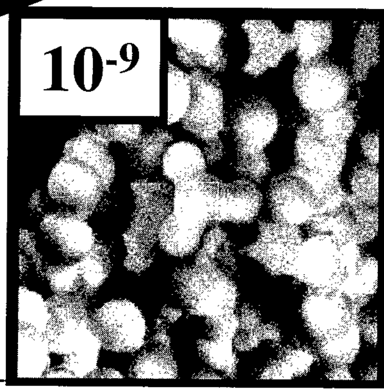
Description in
Nature



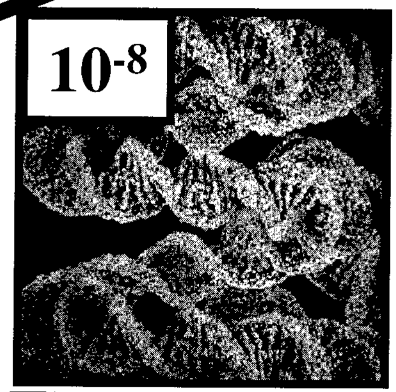
3-D
Model

DNA-scale Devices

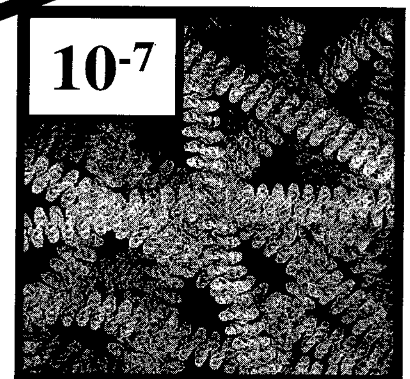
meter



The molecules of DNA



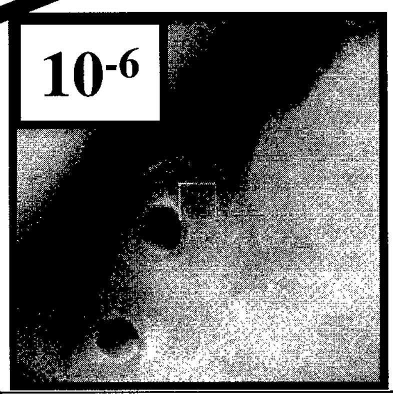
The structure of DNA



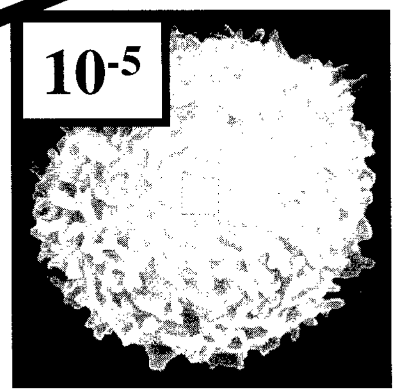
Strands of DNA

Cell-scale Devices

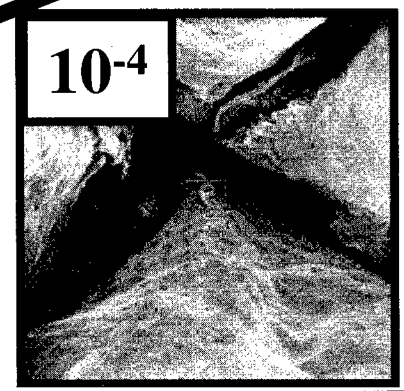
meter



The nucleus of the cell

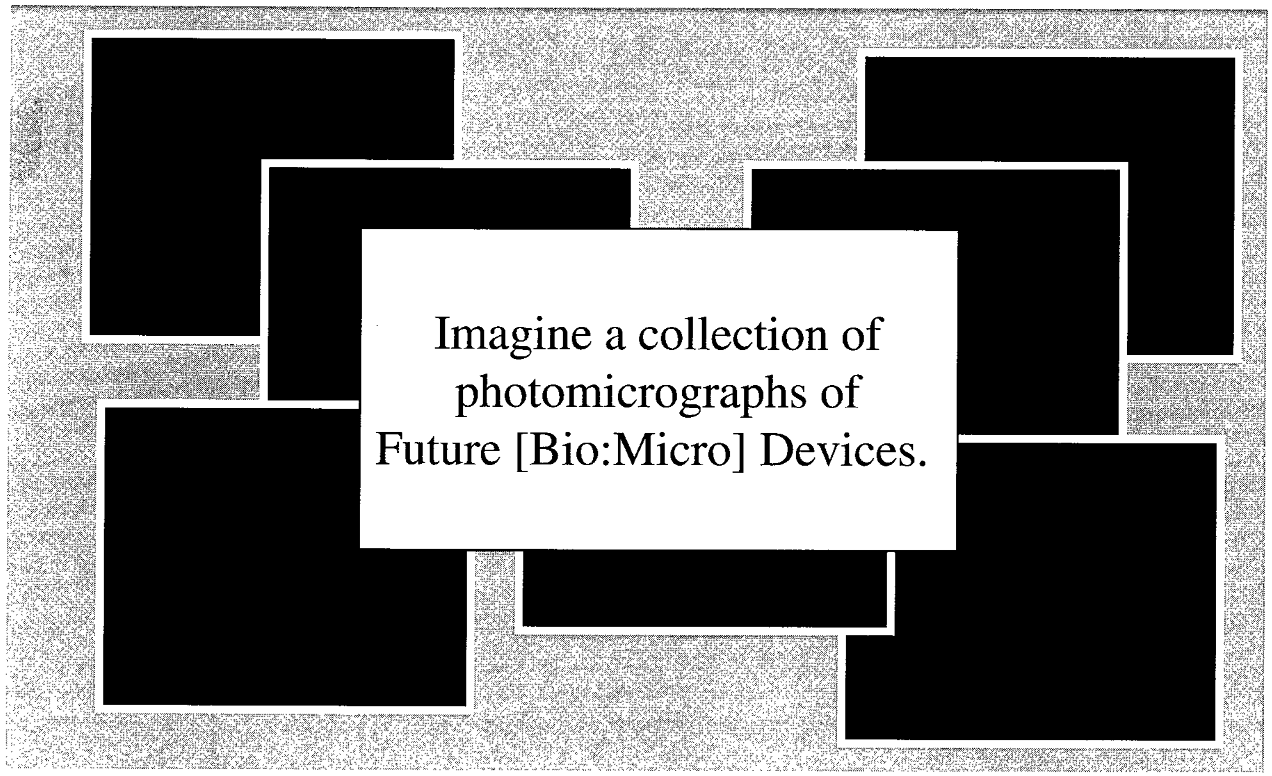


A lymphocyte



Micro-organisms

[Bio:Micro] Devices



Developing a strategic vision

- Stimulate the formation of interdisciplinary research activities focused on fundamentals of the interactions in [Bio:Info:Micro]
- Enable the transition of scientific discoveries into prototype technologies that can be experimentally applied
- Enable the development of new capabilities in realistic system contexts

Stimulating strategic processes

- Leverage existing Bio research activities
- Couple to Info and Micro research
- Transition to IT-based processes
- Develop new “devices”
- Imagine new capabilities
- Transition imagination toward technology
- Establish fundamentally new capabilities

Enable IT-based ...

Measurement

Analysis

Design

Prototyping

Integration

Collaboration

All accessible over the Net

DARPA

➡Preparing for the future

- Visiting advanced research sites
  - Aggressive listening
  - Trends, limits, challenges, opportunities
  - Investment strategies
- Planning [Bio:Info:Micro] meetings
- Planning joint program approaches
- Planning for ***future*** pilot projects

Information Systems Office

Dr. W. M. Mularie
Director

DARPA ISO

Agenda

View of the Environment

Programmatic Themes

Program Implementation

Opportunities

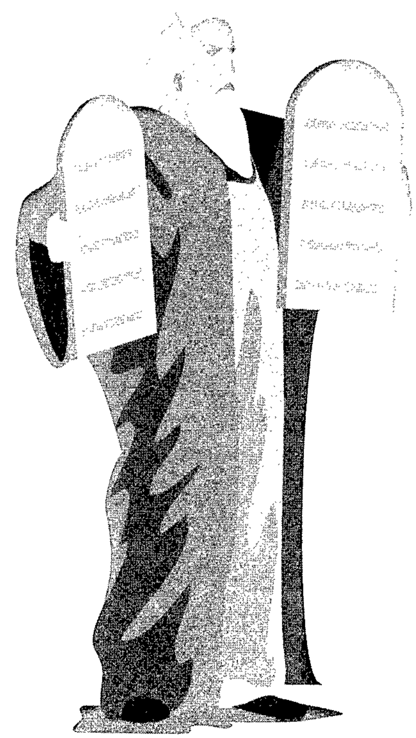
Environment

"What we believe about the world"

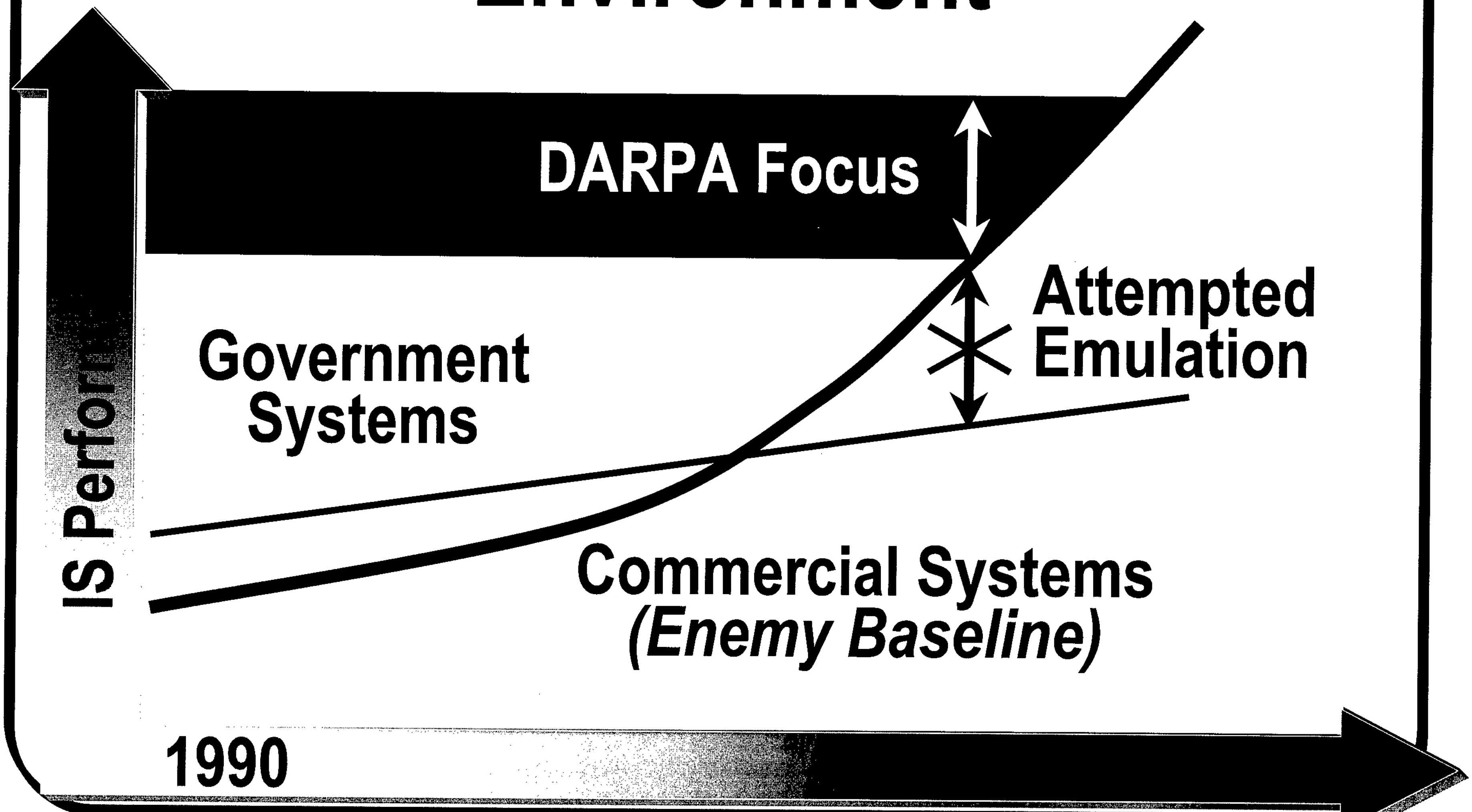
Reflects JV 2010 Information Superiority
- Network Centric Warfare
- Digitization of the Battlefield

Heterogeneous World
- Intra / Inter (Joint)
- Coalition
- Commercial Market Driven

Threat
- Force on Force
- Asymmetric Warfare



Commercial Market Driven Environment



"Recasting role of DoD could create needed advantage in information technologies" New World Vistas Study, USAF
Dr. William M. Mularie and Maj Gen Robert Rosenberg (Ret.)

DARPA

ISO

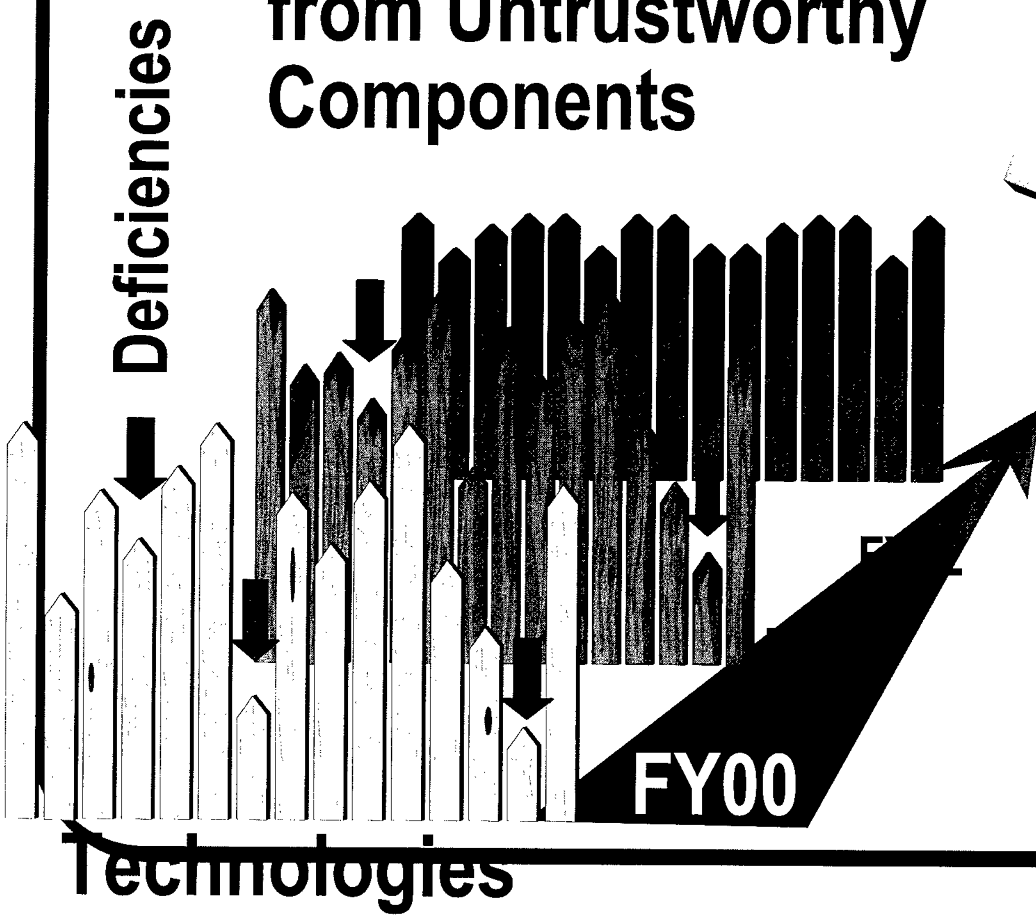
ISO Response

- Strategic Cyber Defense
- Total Information Awareness
- Command & Control

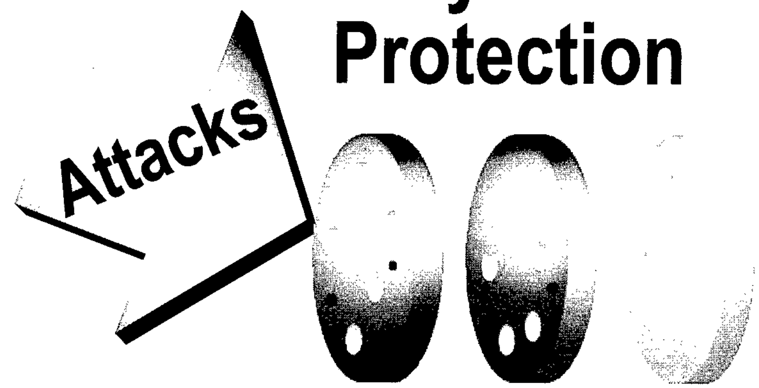
Strategic Cyber Defense

(Information Assurance)

Trustworthy Systems from Untrustworthy Components



Layered Protection



- Prevention
- Detection
- Tolerance

ISO Response

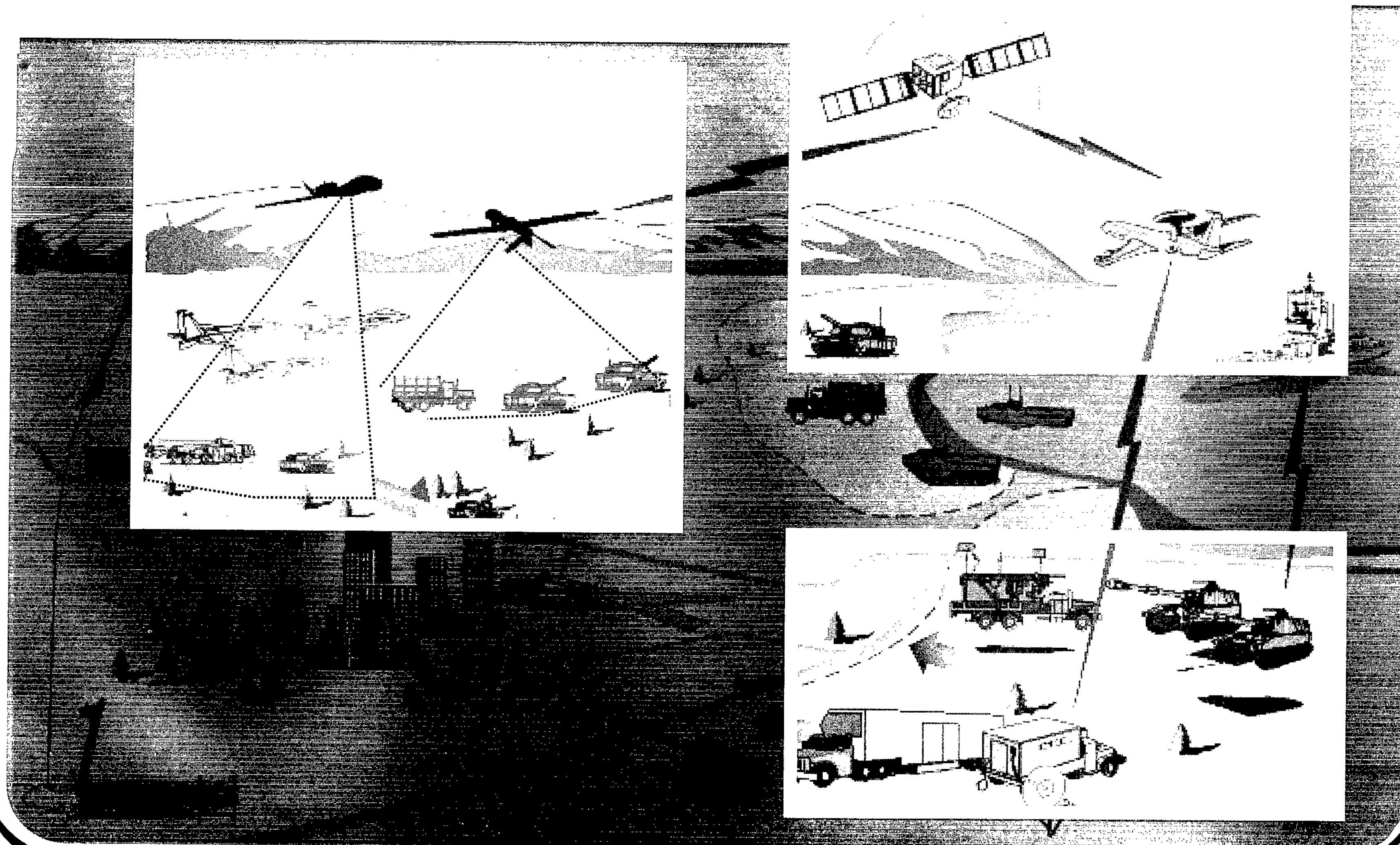
Strategic Cyber Defense

Total information Awareness

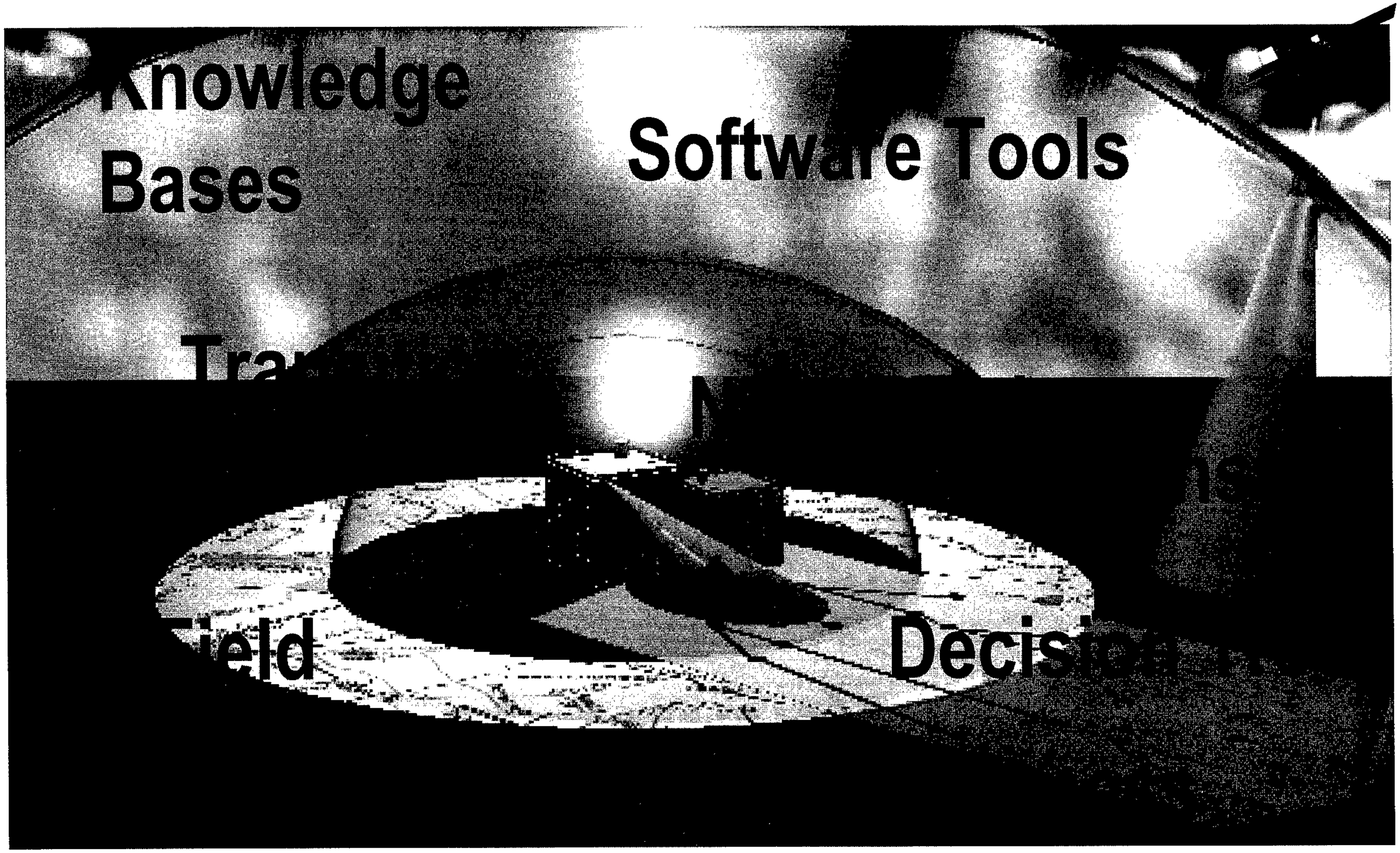
Command and Control

DARPA ISO

Force on Force - JV2010



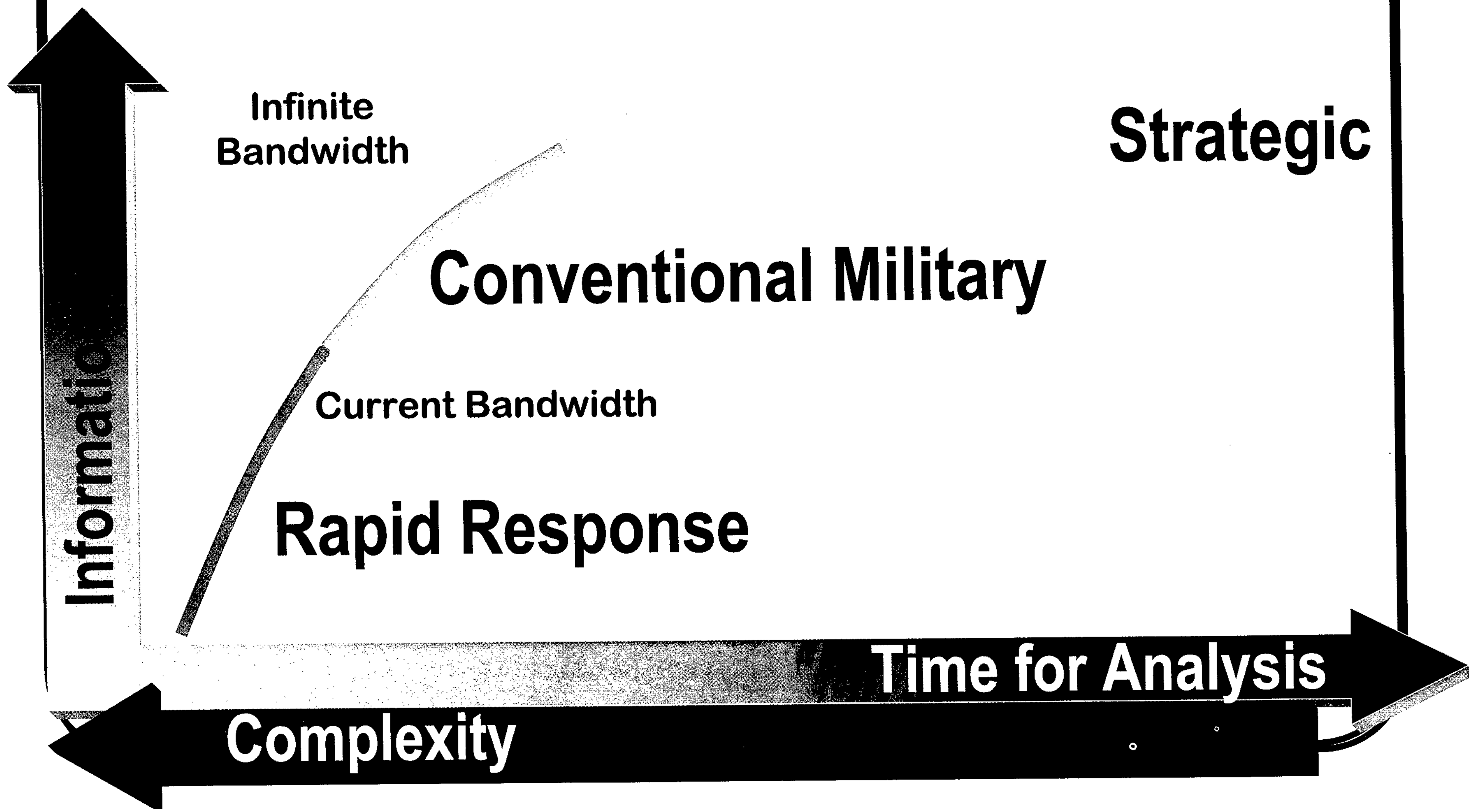
Asymmetric Warfare



ISO Response

- Strategic Cyber Defense
- Total Information Awareness
- Command and Control

Command and Control



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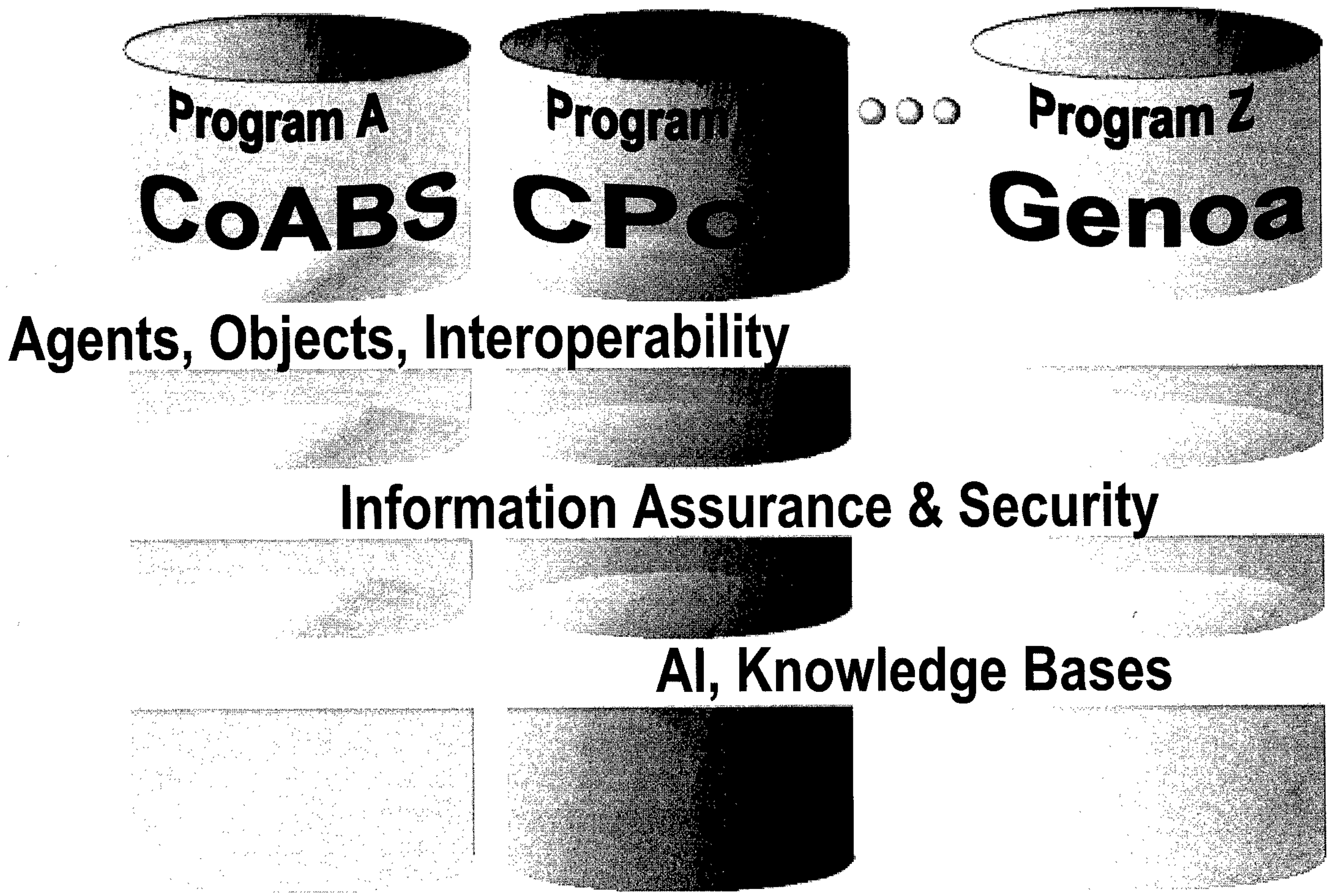
ISO Implementation

Strategic Cyber Defense
- Information Assurance
- Information Survivability

Total Information Awareness
- CoABS
- HPKB/RKF
- Project GENOA
- IU/IUFP

Command & Control
- ALP
- JFACC
- CPoF
- Active Templates
- JL-ACTD
- BADD

ISO Technology Base



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ISO Broad Agency Announcements

• Active Templates	Summer 99
• Image Understanding for Force Protection	Summer 99
• Joint Forces Air Component Commander	Summer 99
• Rapid Knowledge Formation	Summer 99
• Project Genoa	Winter/Spring 00
• Strategic Cyber Defense	Summer 99

DARPA ISO

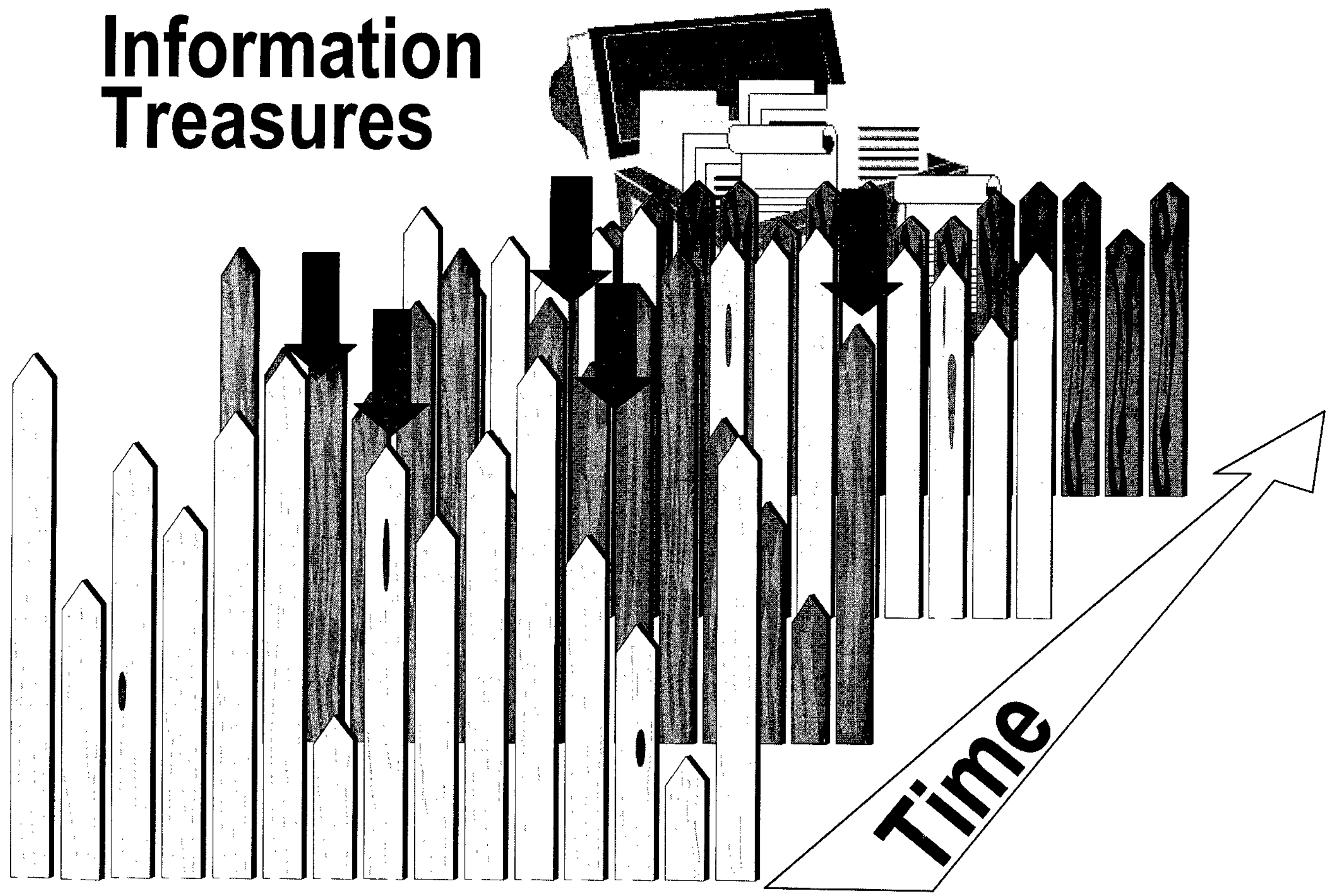
Strategic Cyber Defense

O. Sami Saydjari
Program Manager

DARPA

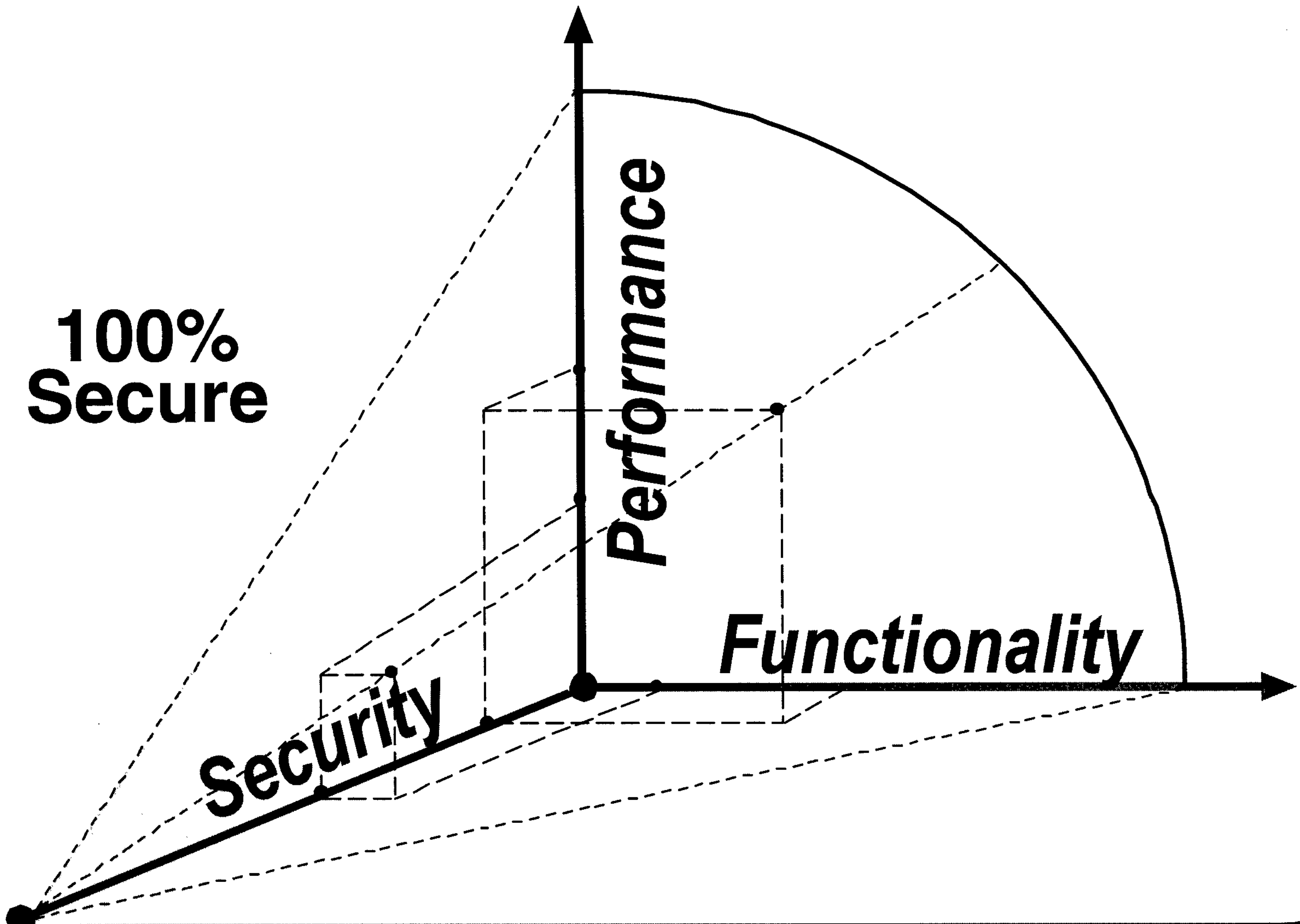
Information Assurance

ISO



Risk-Balanced, Optimizing Strategy

Tradeoffs

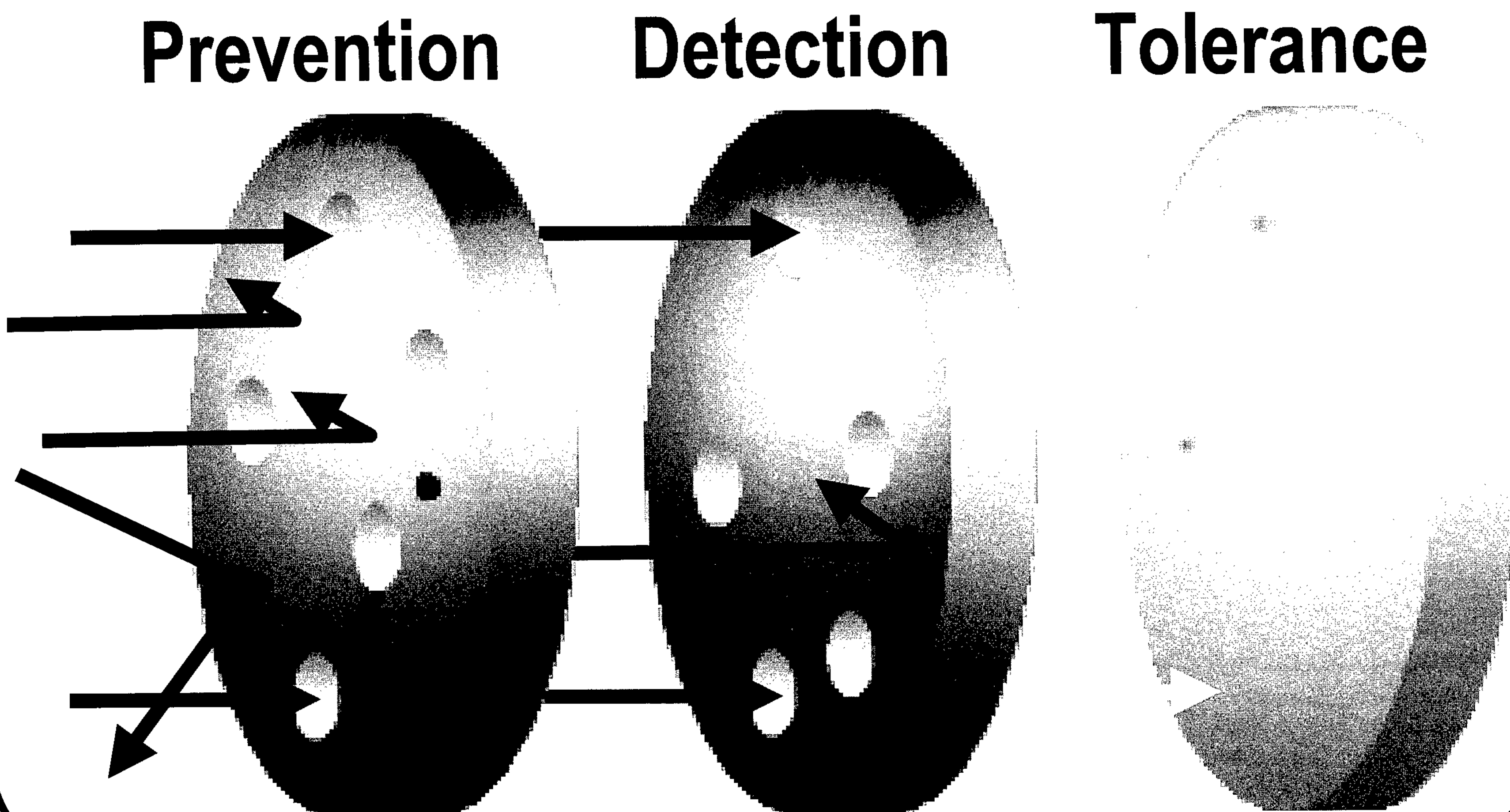


Challenging Questions

Commander's Attack Triage

- Am I under attack ?
- What is the nature of the attack ?
- What is mission impact ?
- When did attack start ?
- Who are the adversaries?
- What can I do about it ?
- What is the long term solution?

Layered Protection



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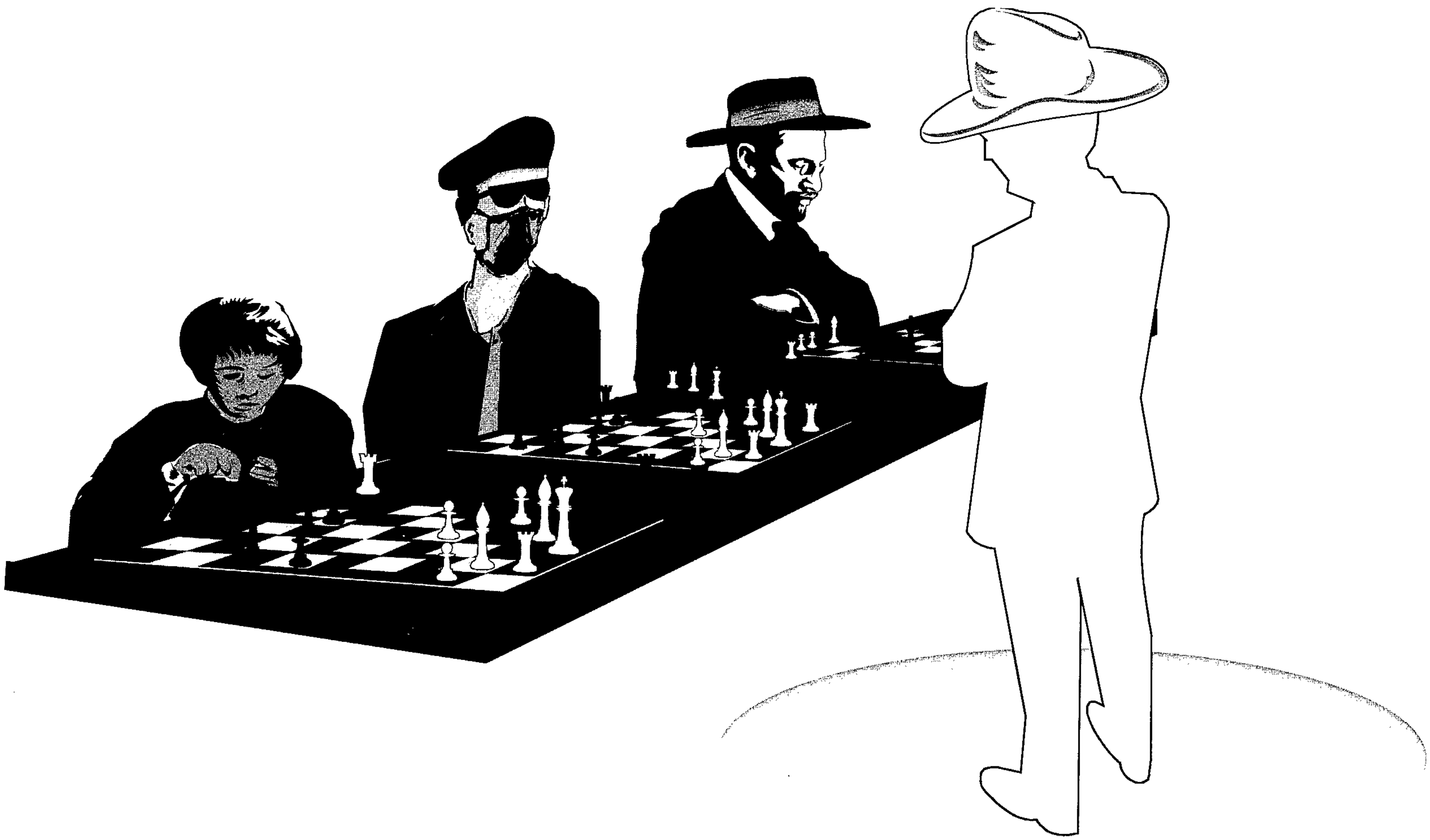
ISO

Game Theory



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Strategic Cyber Defense

Cyber Defense Strategy:
Nat'l Level I&W and Response Integration

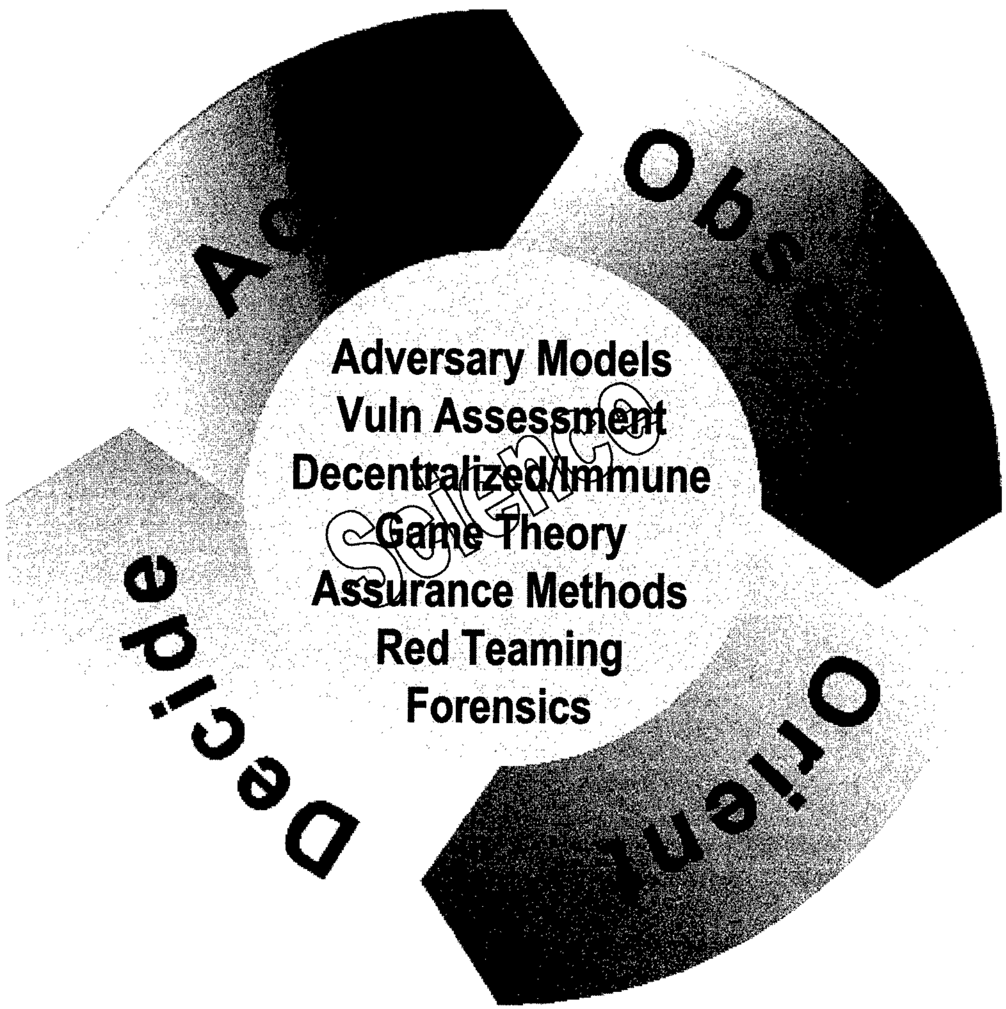
Cyber Sensors & Exploitation	Cyber State Awareness	Cyber Command & Control

Observe → Orient → Decide → Act

Info Assurance Science & Engineering

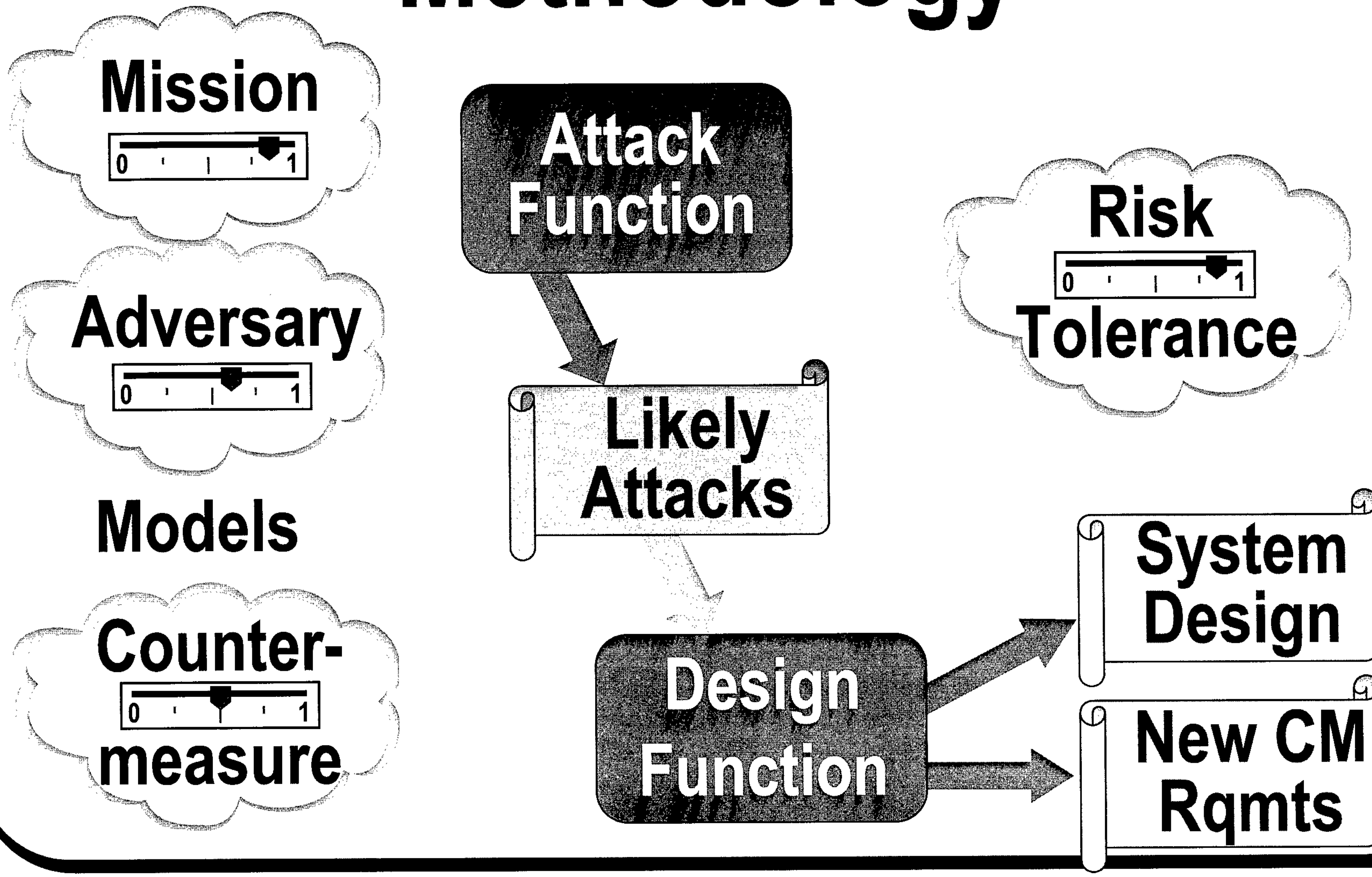
DARPA ISO

Strategic Cyber Defense:



DARPA ISO

System Assurance Methodology



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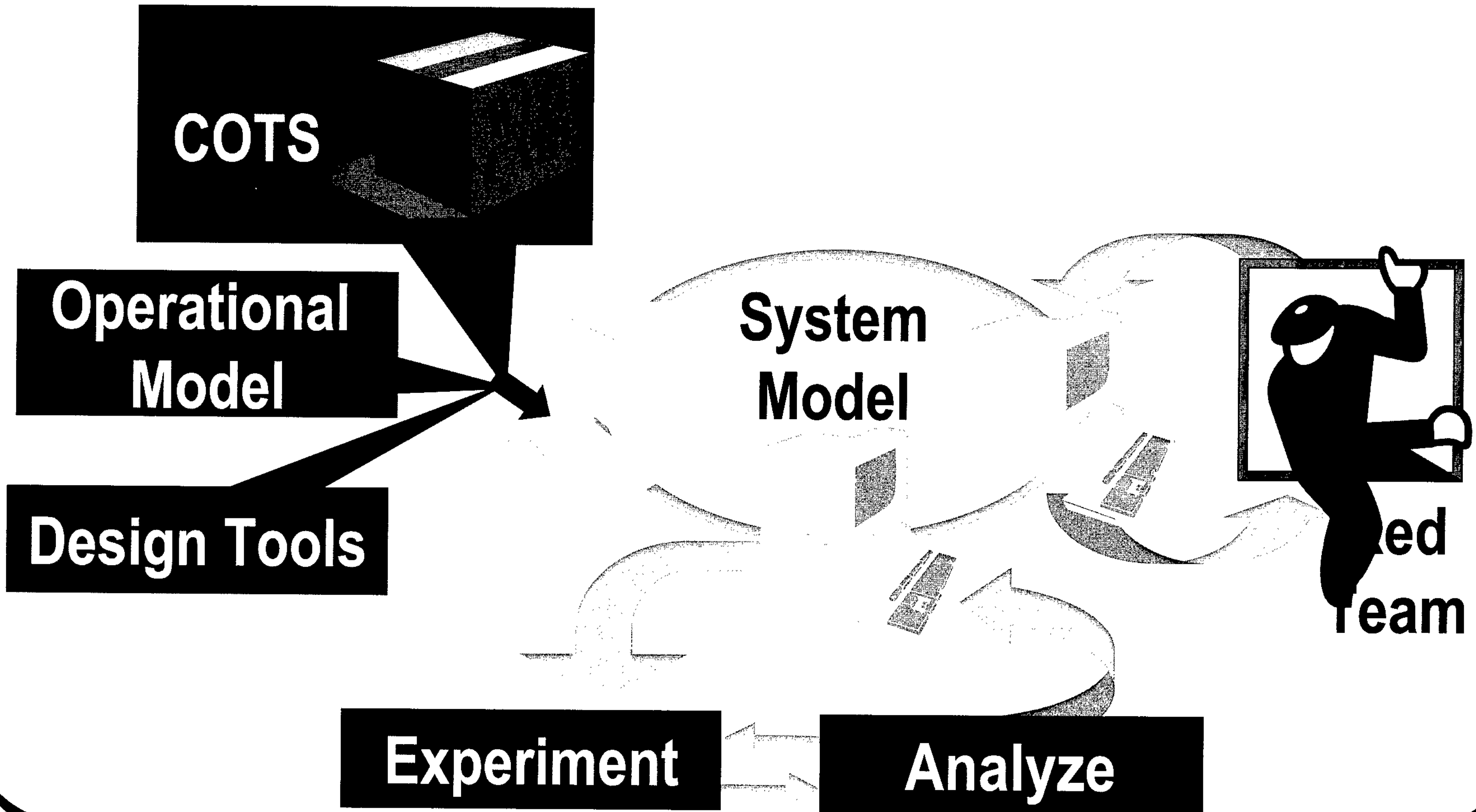
Trustworthy Systems from Untrustworthy Components



Control of Agent Based Systems

Jim Hendler
Program Manager

DARPA

Agents and the Military Need

ISO

Assignment problems ⟷ Auction mechanisms

Bursty bandwidth use ⟷ Mobile code

Open source information ⟷ Info agents

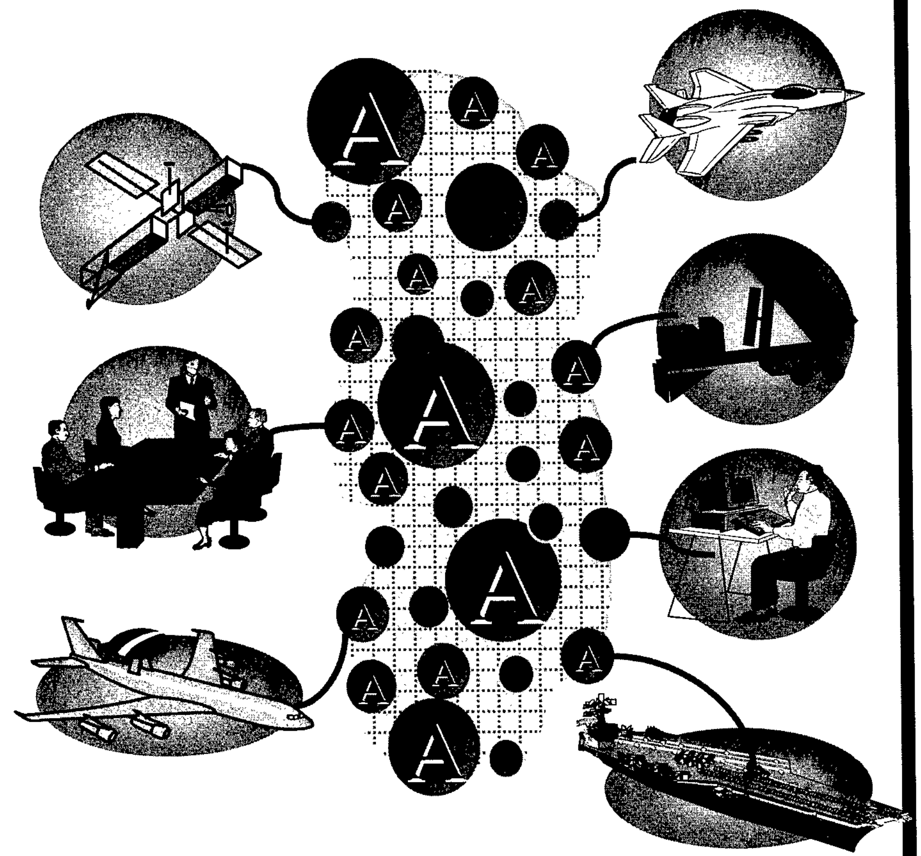
Interoperability ⟷ brokering

And many more

What is an Agent?

An agent is a software component or system that is:

- Communicative
- Autonomous
- Capable
- Adaptive



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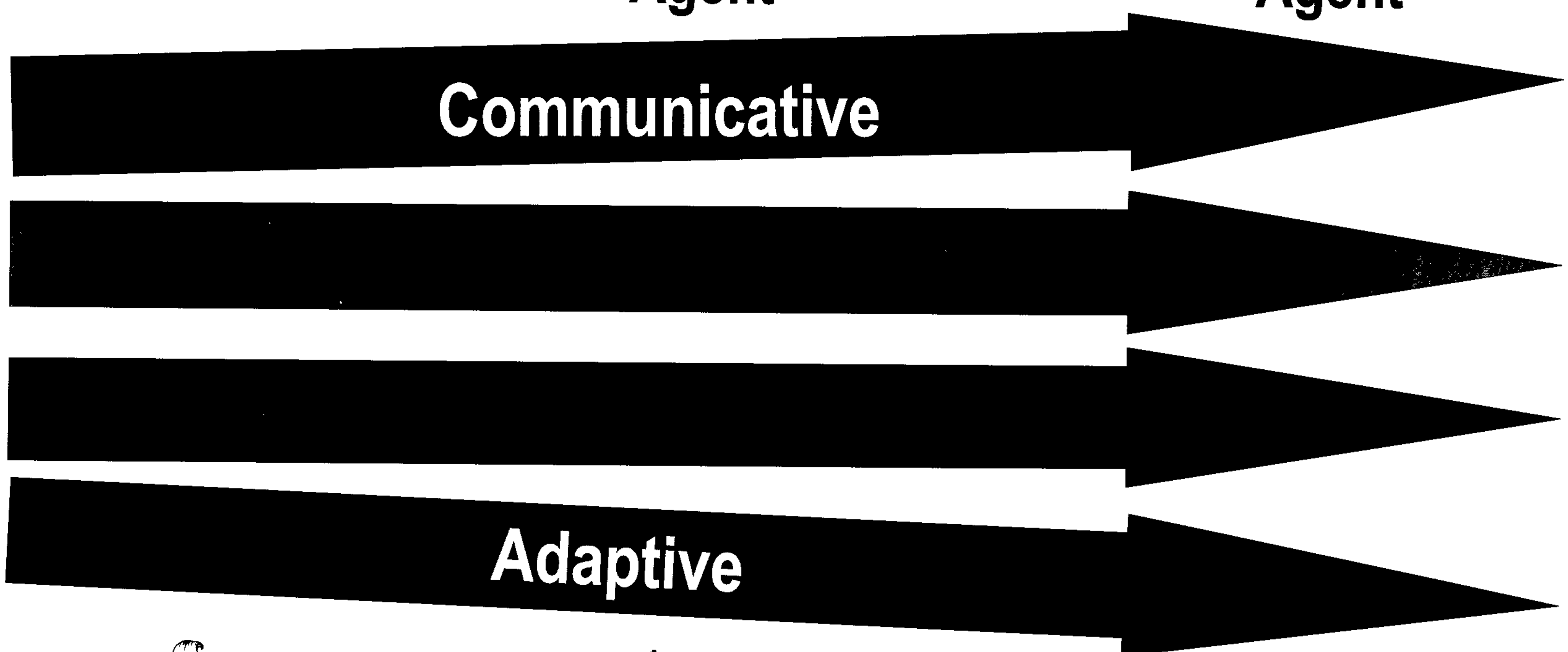
Agent Evolution

A critical zone

Where we are → *The "desire"*

Web Agent | Information Agent | "Intelligent" Agent



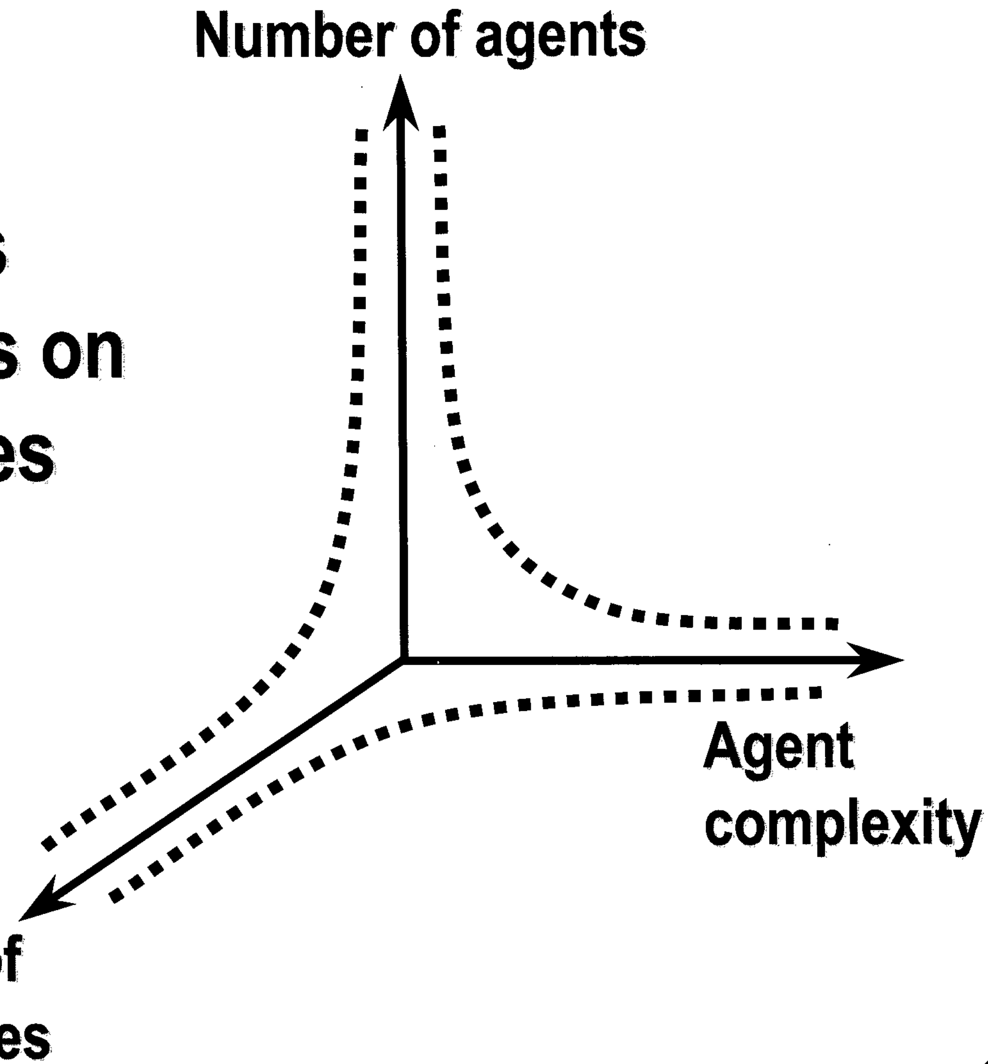
Gather Nuts

Fetch, point, carry, etc.

Make it so

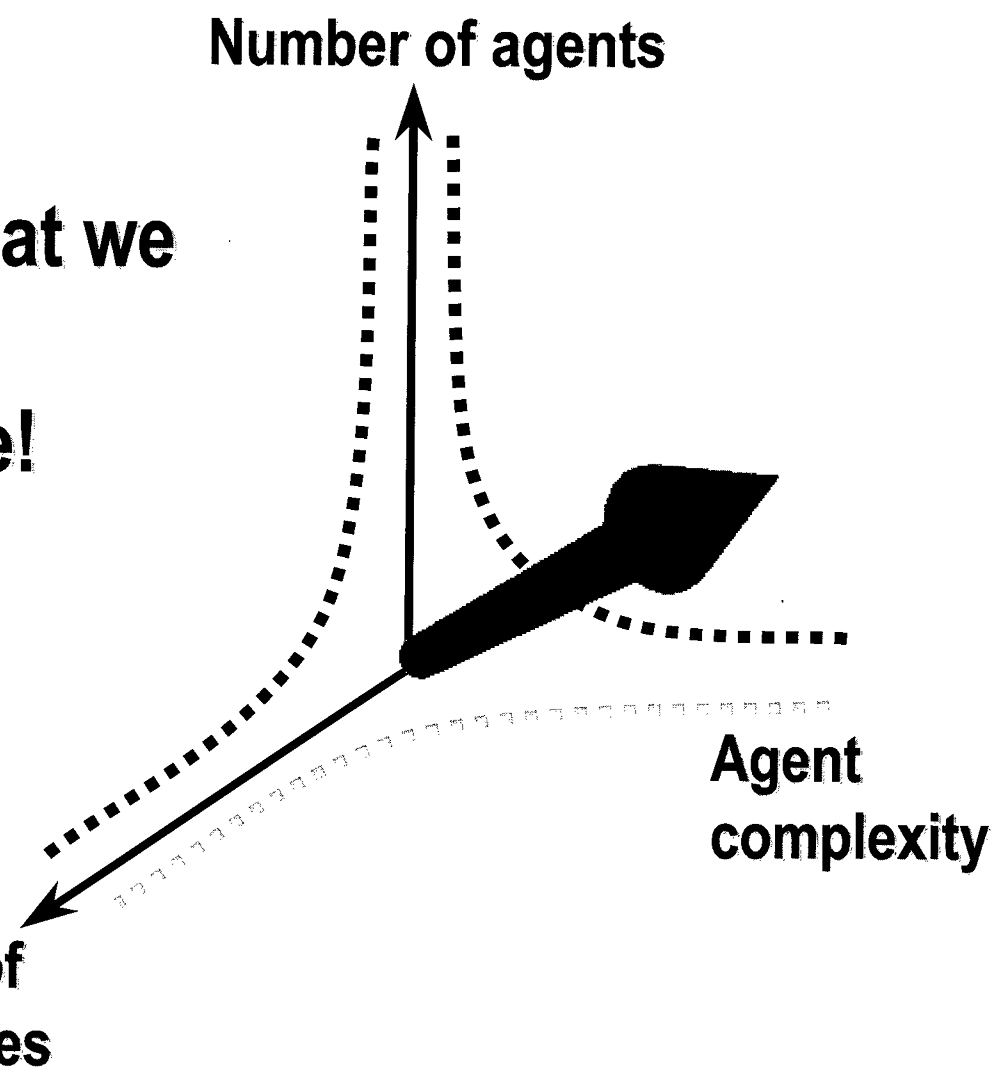
Agent Scaling Experiments

Current experiments cluster near the axes on the orthogonal planes



Agent Scaling Experiments

CoABS will show that we can get out into the middle of this space!



Information Agent Challenge

C
o
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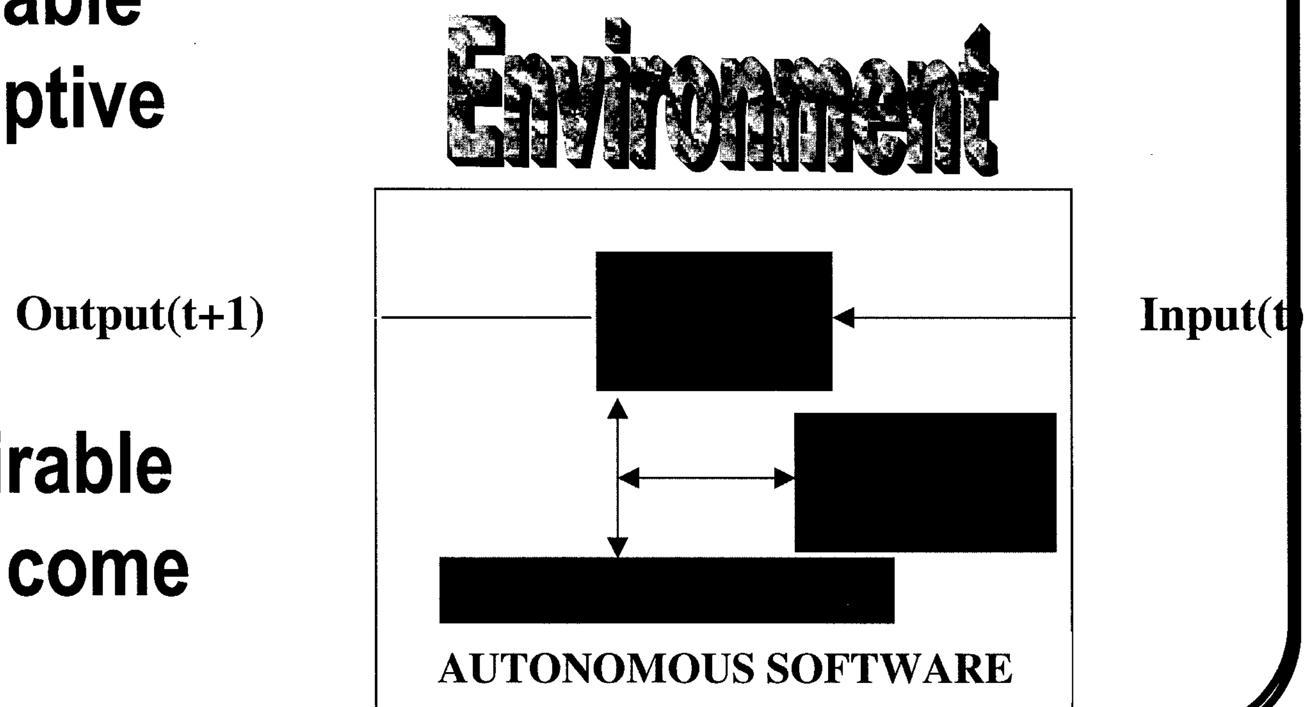
i
t
y

- Communicative
- Autonomous
- Capable
- Adaptive



These desirable properties come at a cost...

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CoABS Focus

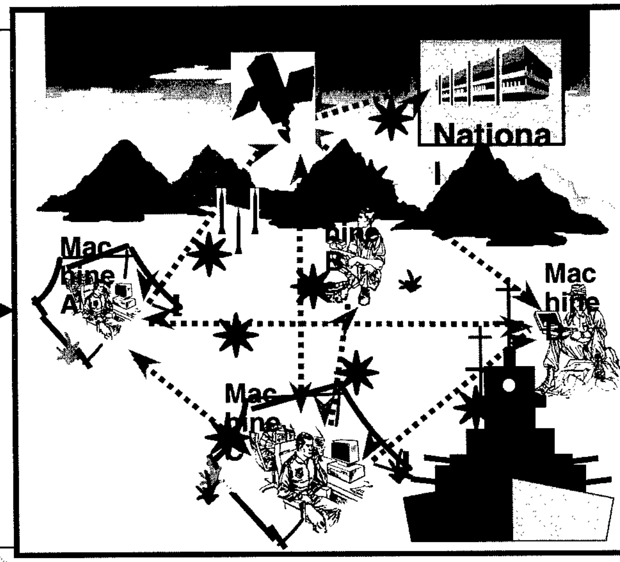
Examine these technologies in the context of an evolving military information management vision

- AFSAB Information Management, AF C2 Conops
- Army after next
- Cooperative Engagement Capability
- and numerous others

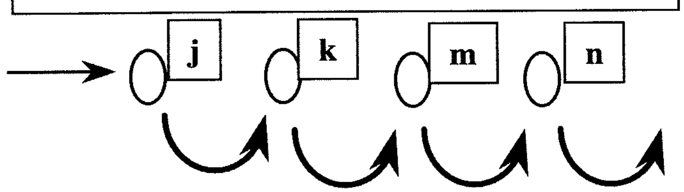
CoABS: Meeting the Challenge

Military TIEs stress *integration*

- OOTW
- Ballistic and Theatre Missile Defense
- Coalition Force Interoperability



Site j "costs" c_j to visit and has probability p_j of success.
Visit sites until none left or successful.



Expected cost = $c_j + (1-p_j)c_k + (1-p_k)(1-p_j)c_m + \ldots$

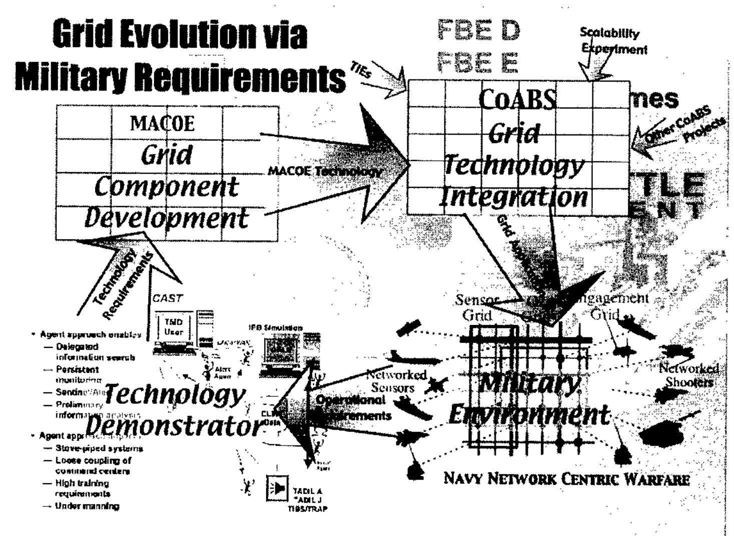
Scientific TIEs stress *scaling*

- Negotiation Experiments
- Mathematical Analyses
- Control Scheme Comparison

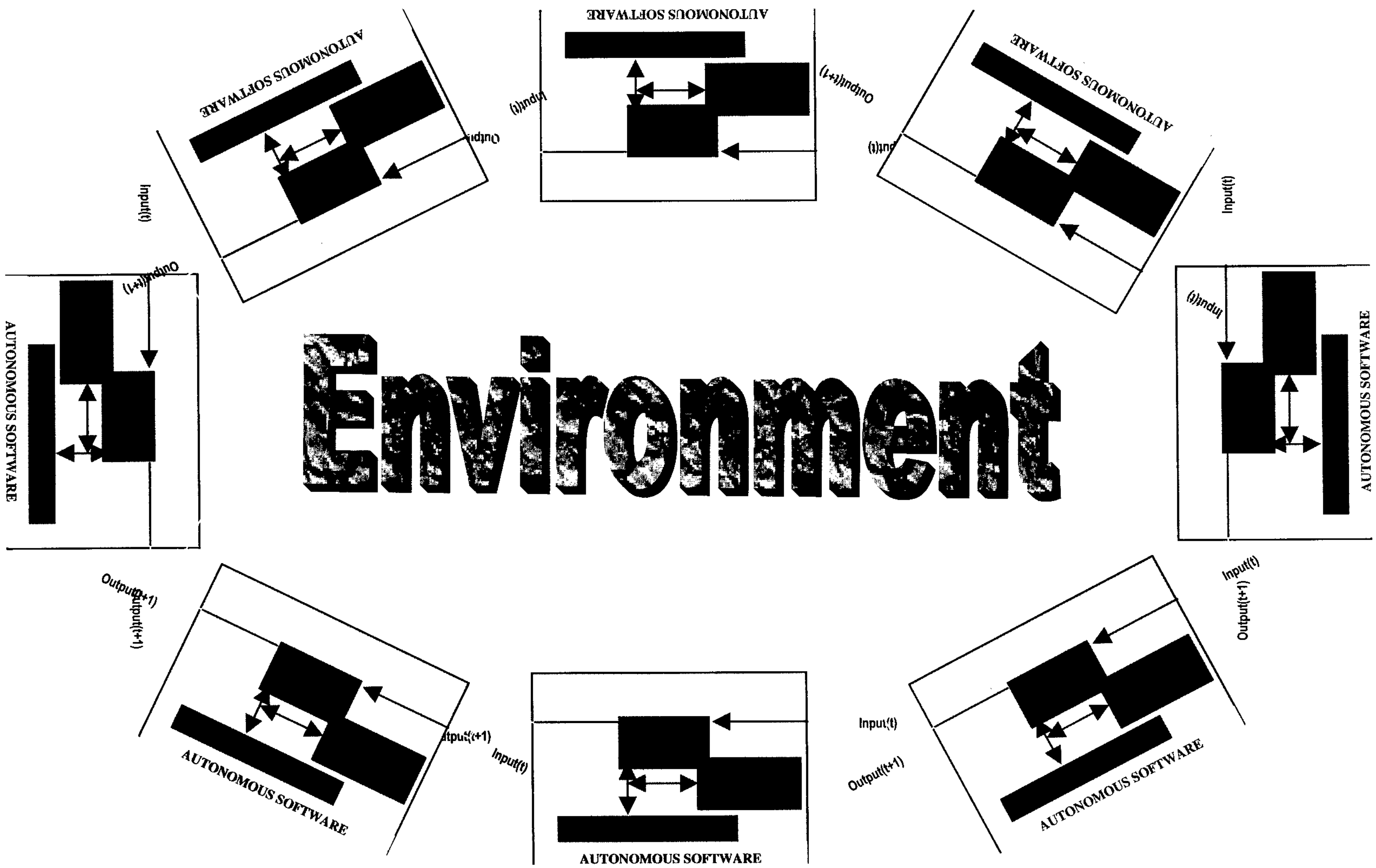
CoABS Agent Grid

CoABS "Grid" provides a basis for tool development for DARPA and military computer programs

- Legacy systems wrapping
  - Middleware approach
  - Service based
  - Logging/reporting tools included
- New systems development
  - Tool refinement, testing, integration

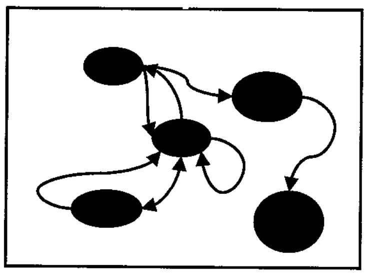


The "N-agent" Problem



Beyond CoABS: Agent Science

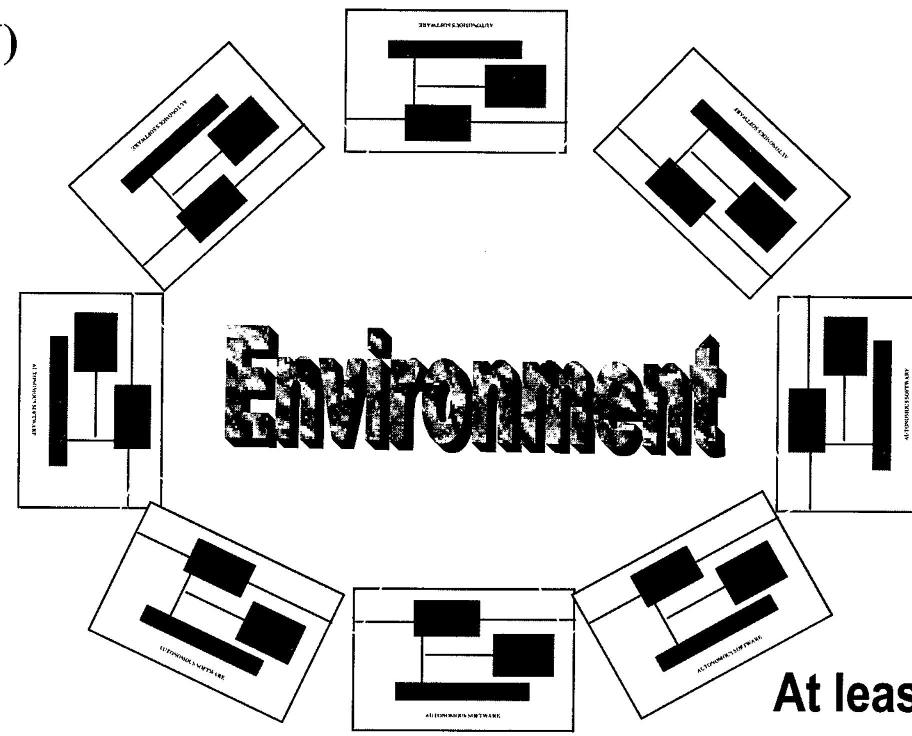
0101010101010101010101011010101010101010101010101001010101...



$O(1)$
$O(\log N)$
...
$O(2^n)$

The Turing Machine

Cannot model agent-based systems!



At least Undecidable

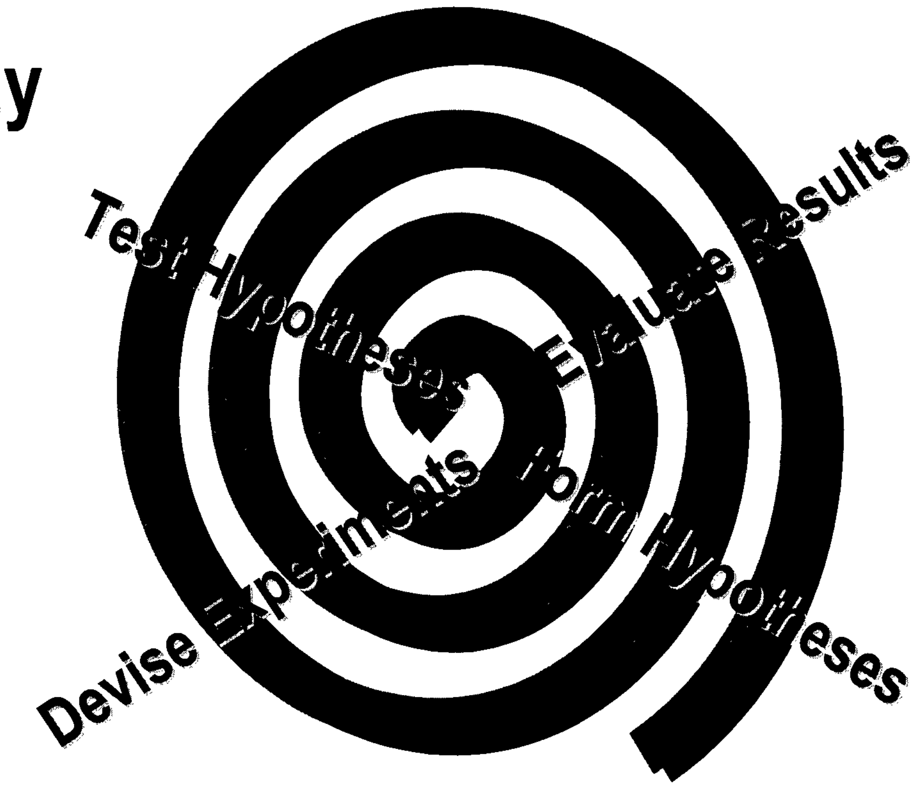
The Science of Agency

How do we apply scientific methodology to agent-based computing?

- Bring the science of computing out of the 1950s

1999 Workshop

- Leading computer scientists in the US and abroad being invited



Summary

DARPA is exploring the use of agents for a wide range of military needs

- CoABS focuses on critical challenges
  - interoperability of legacy systems
  - scaling of multi-agent systems

DARPA is interested in helping the computer science community to explore the underlying theory of agent-based computing

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Total Information Awareness

J. Brian Sharkey
Deputy Director,
Information Systems Office

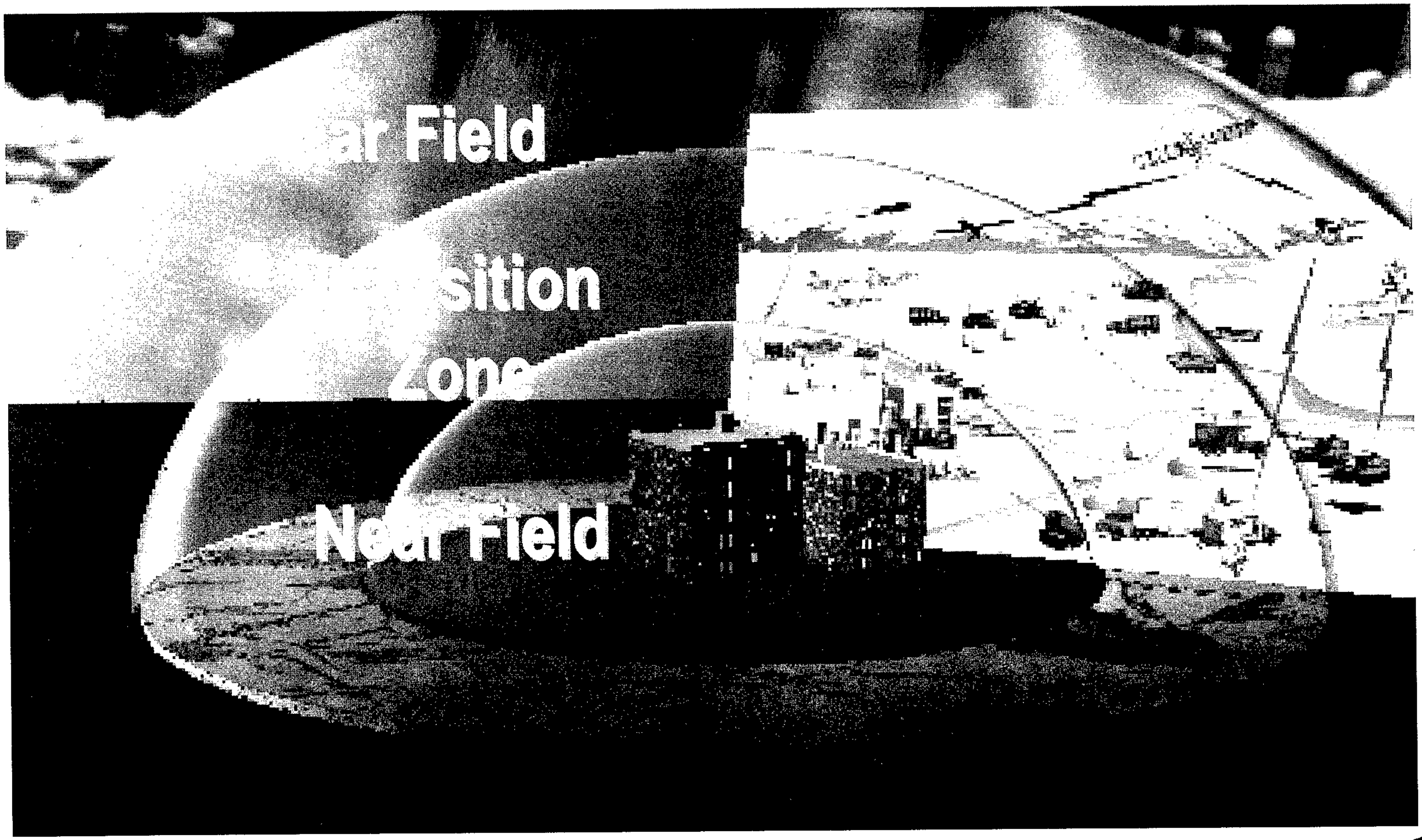
DARPA

ISO

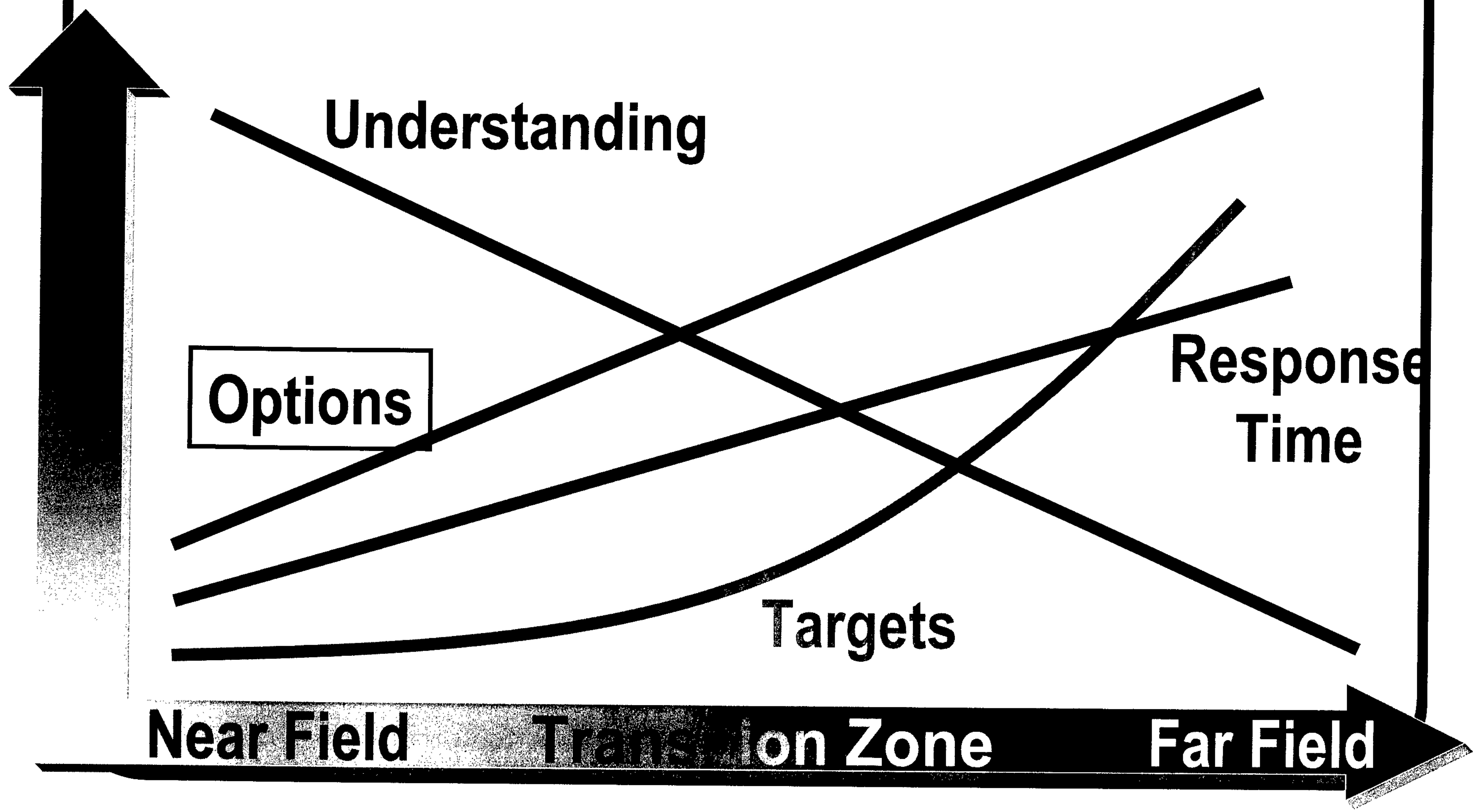
Asymmetric Warfare

Source / Type	Nation State	Trans-National
Symmetric	X	
Asymmetric	X	X

Environment



Understanding the Environment



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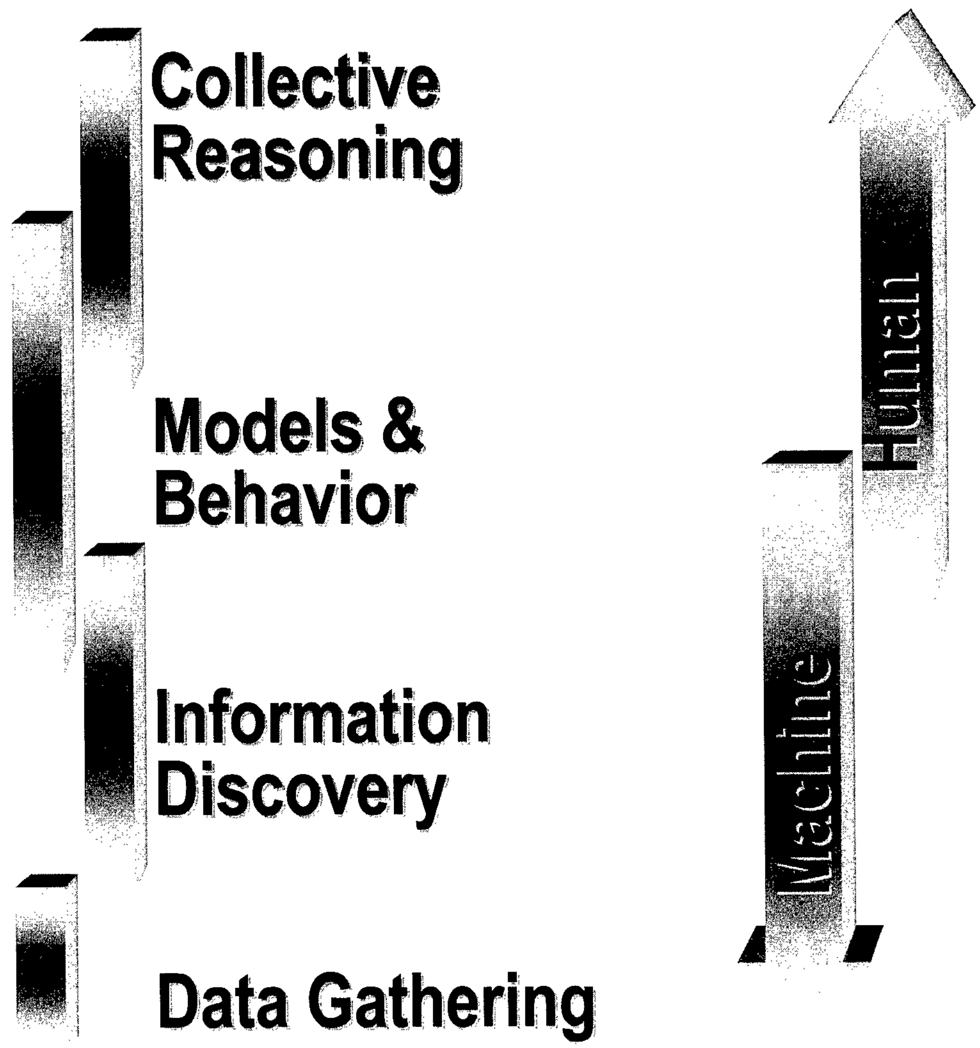
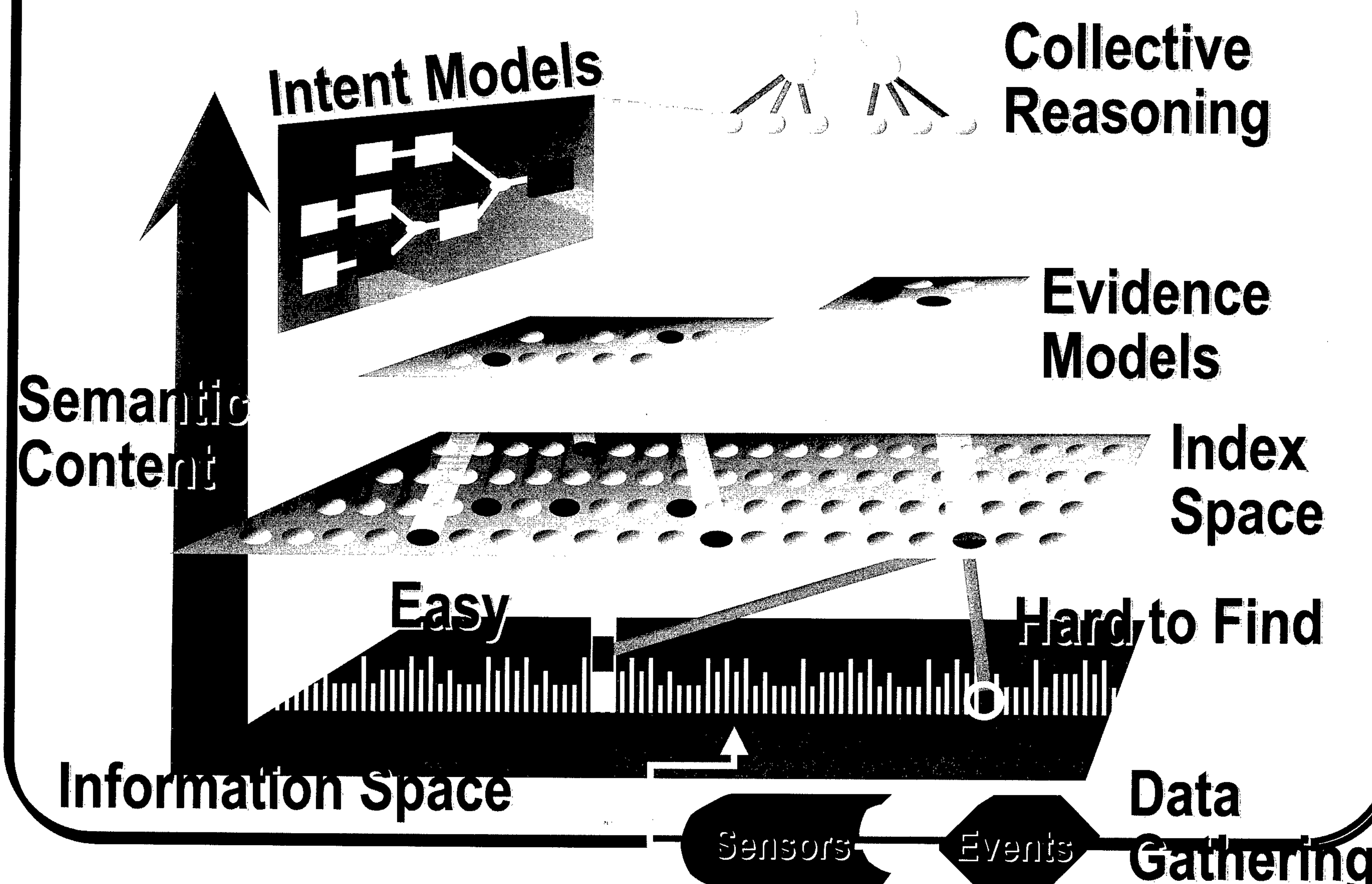
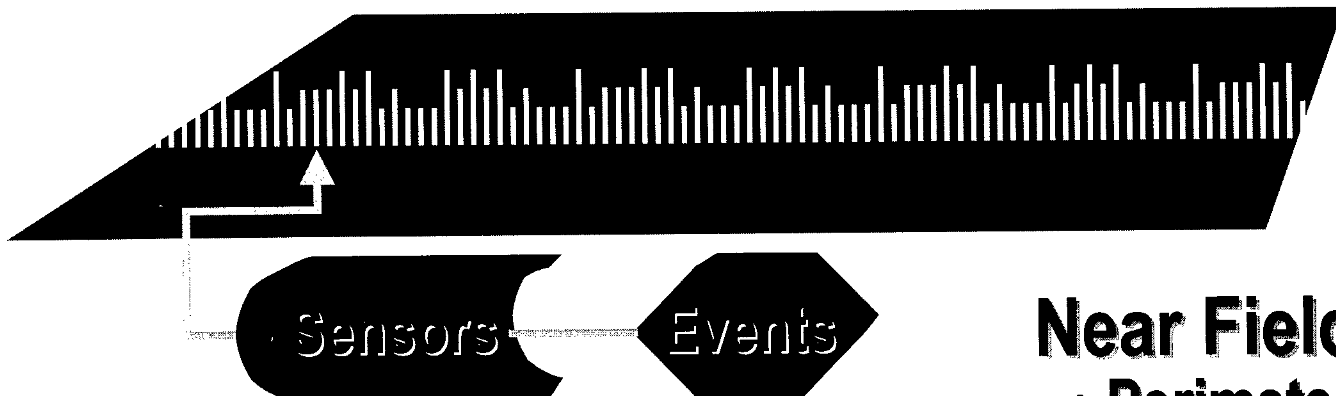
Total Information Awareness

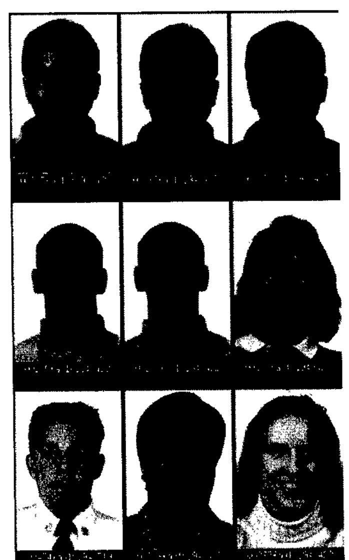


Total Information Awareness



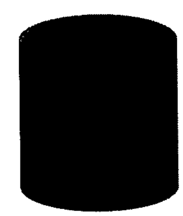
Data Gathering



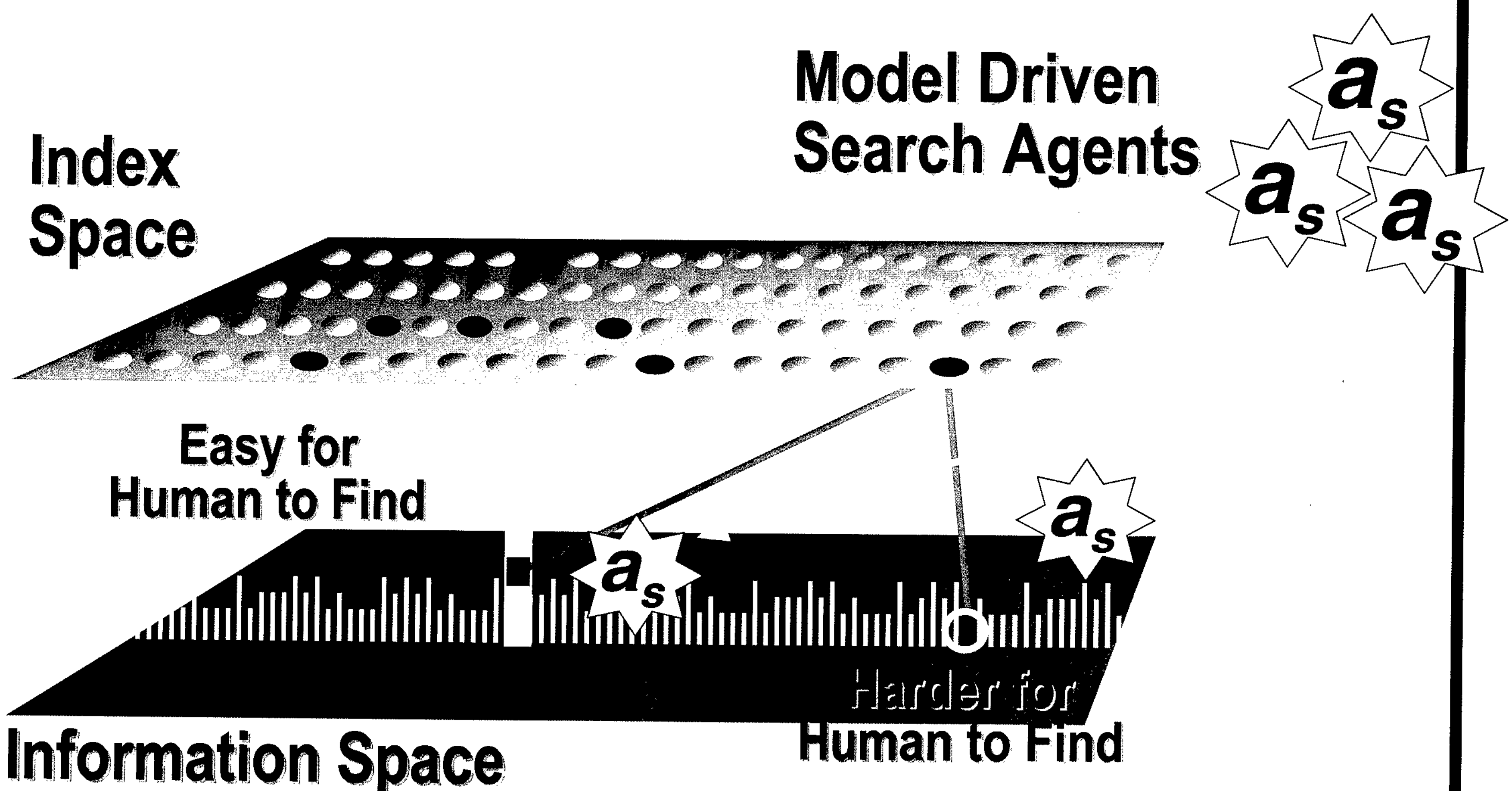


Near Field
- Perimeter Security
- People Tracking
- Face Recognition
- News Bulletin

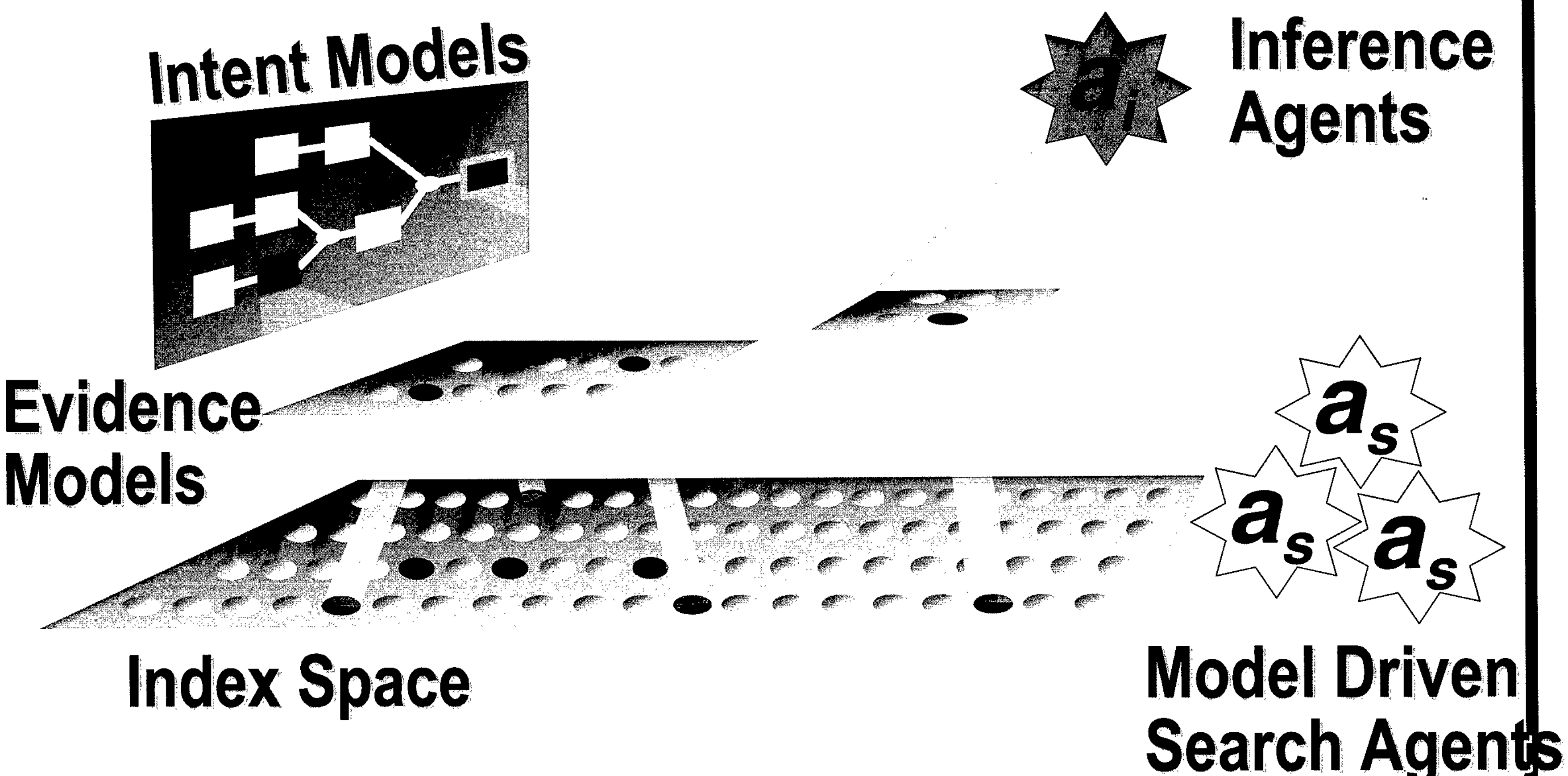
Far Field
- Data Bases
- Data Mining
- Heterogeneous Search



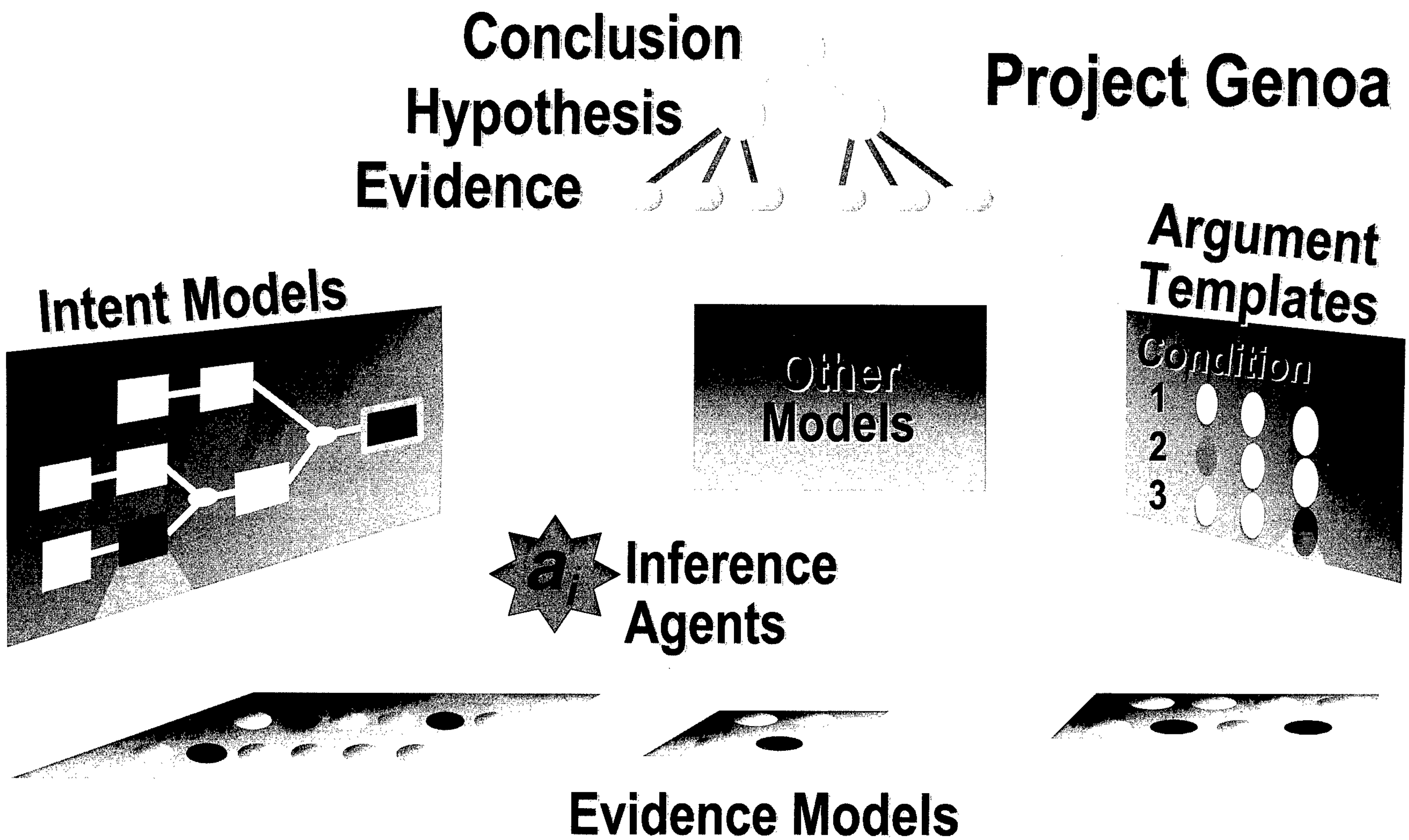
Information Discovery



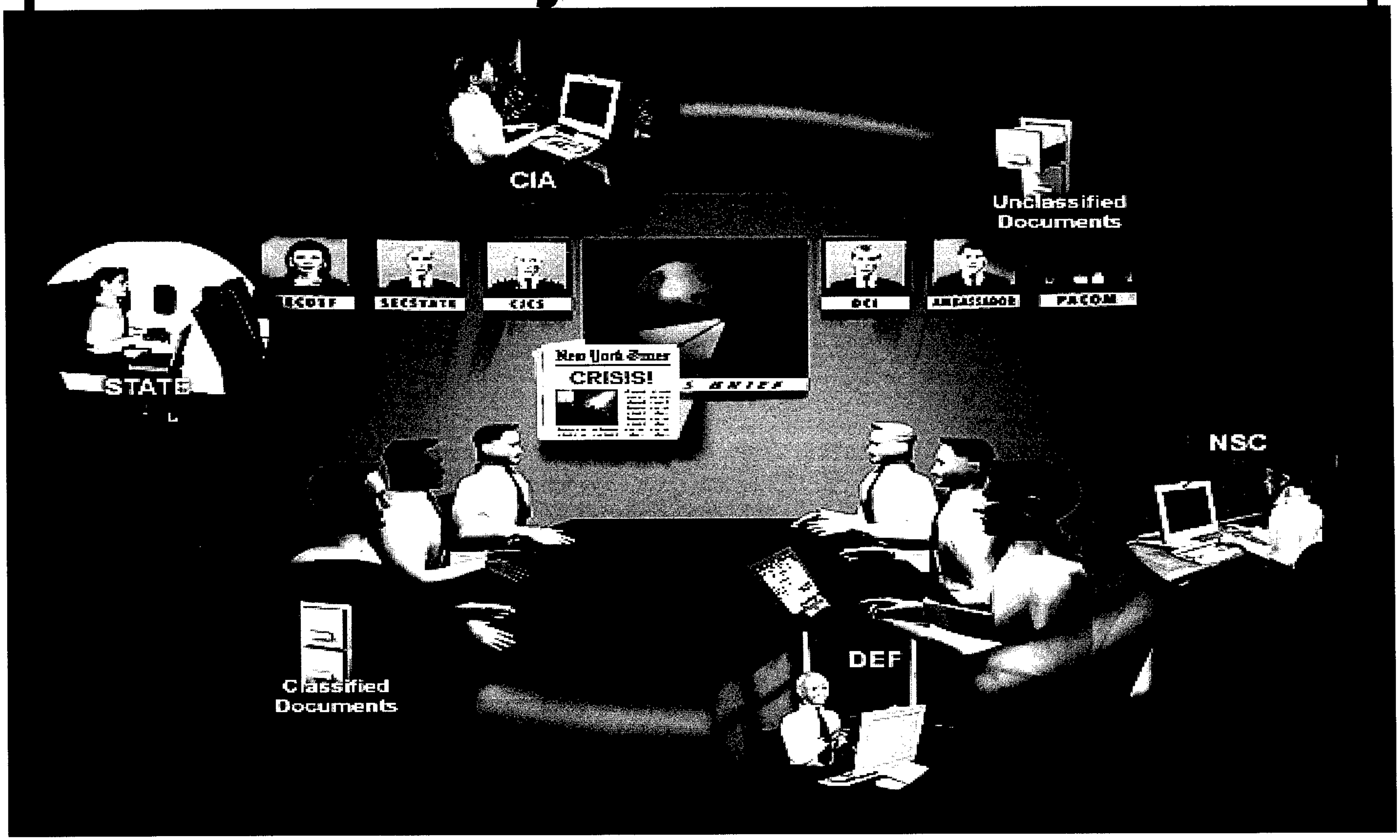
Models and Behavior Analysis



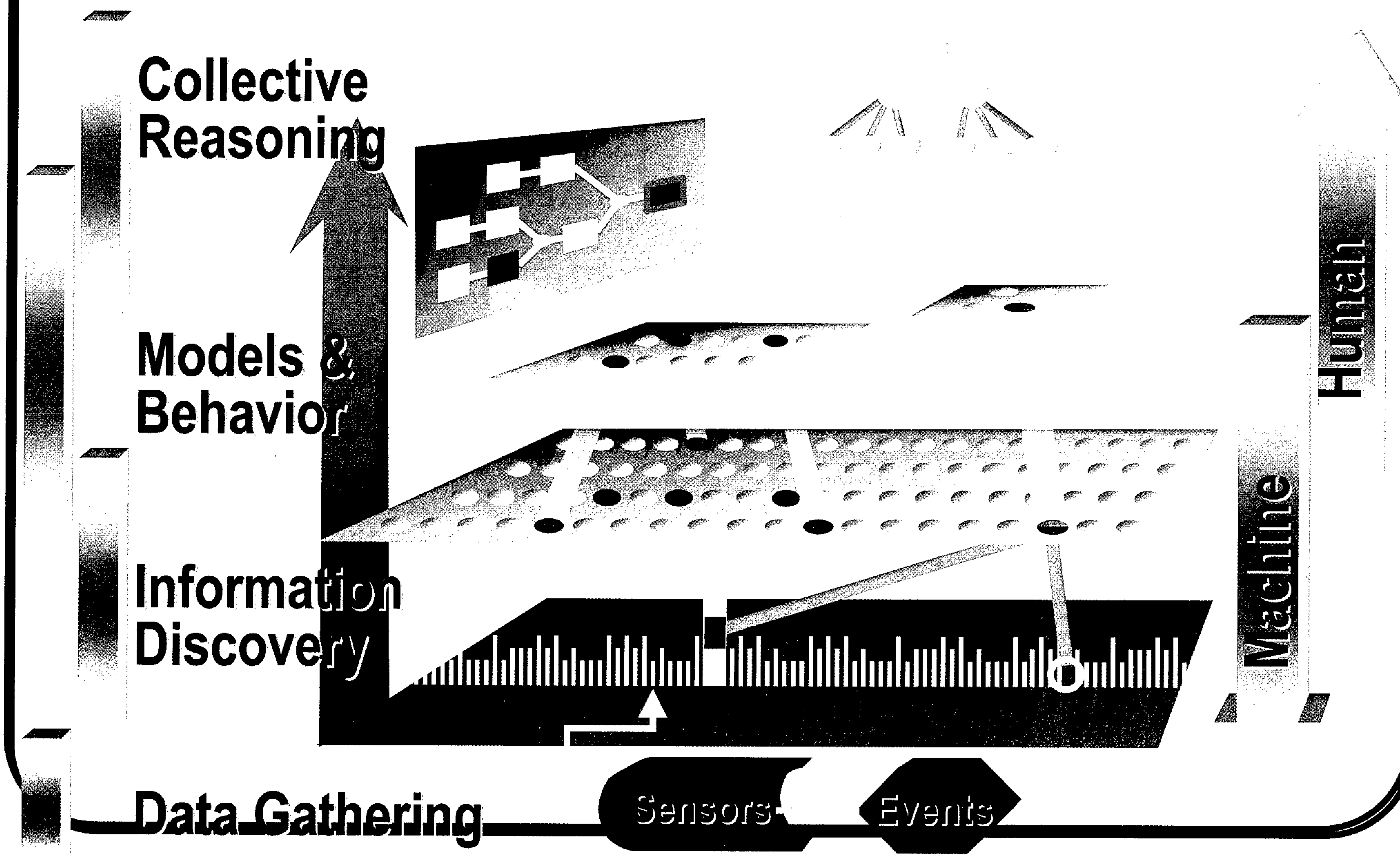
Collective Reasoning



Project Genoa



Total Information Awareness



Collective Reasoning

Collective Reasoning

Information Discovery

Models

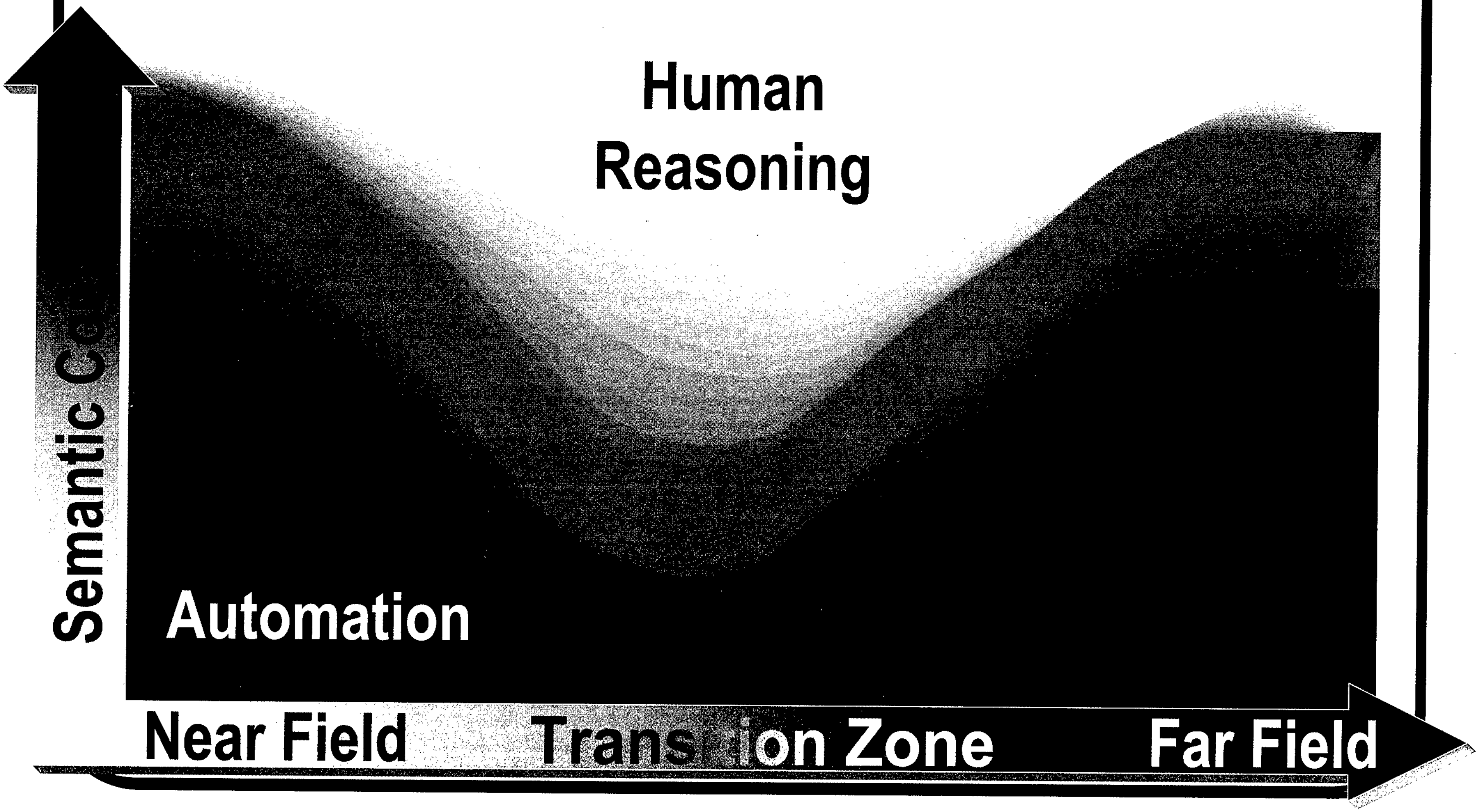
Information Discovery

Data Gathering

Data Gathering

Near Field | Transition Zone | Far Field

Humans and Computers



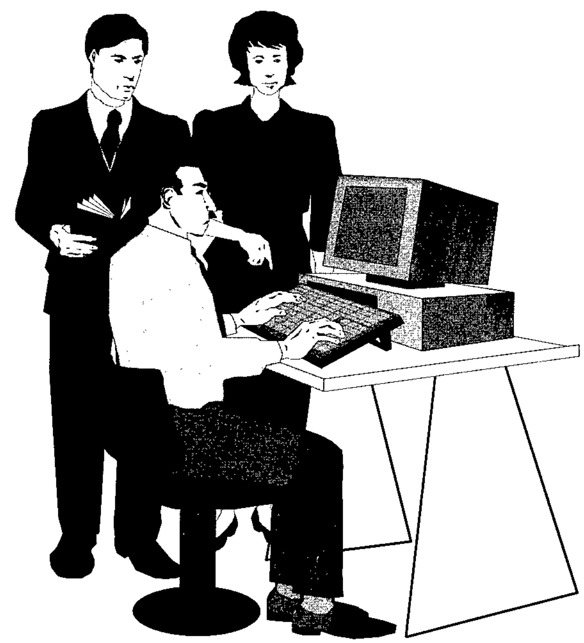
Rapid Knowledge Formation

Murray Burke
Program Manager

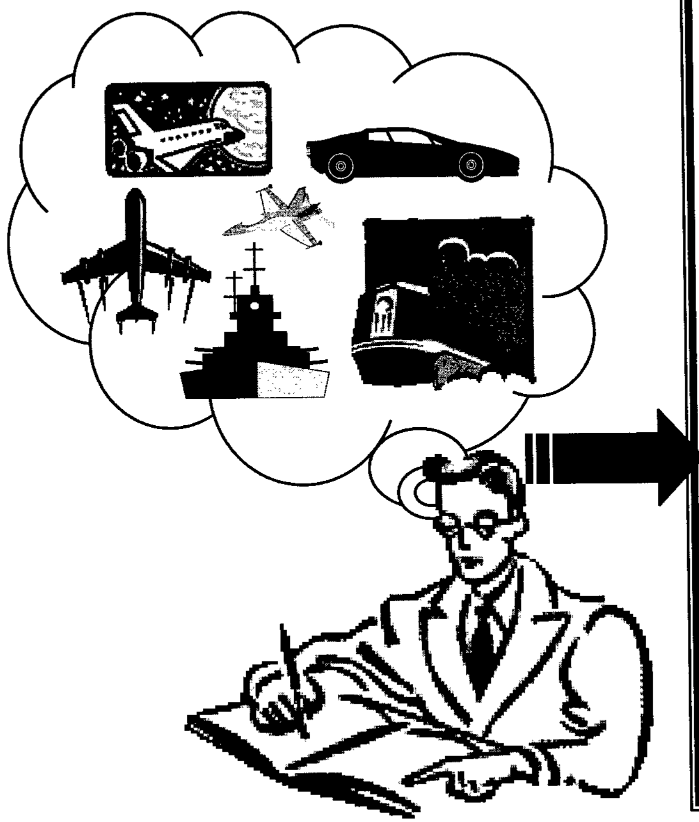
DARPA ISO

Grand Vision

- Experts Enabled to Directly Enter Knowledge
- Massive Libraries of Reusable Knowledge Throughout WWW



What's Hard?



$\forall x, p1, p2.$

vehicle(x) $\Leftrightarrow$

physical_object(x) and

self-propelled(x) and

can(move(x), $p1$, $p2$).

$\forall x, c.$ cargo(c) $\Rightarrow$.....

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Rapid Knowledge Formation

- Human -
- KB Interaction

- Knowledge
- Formation

•Knowledge
•Base

- Understand Current Knowledge
- Enter New Knowledge
- Correct Errors

- Theory Manipulation

Human-KB Interaction

- Natural Language Entry
- Discourse Understanding
- Sketching & Diagram Input
- Explanation

Knowledge Formation

- Reasoning by Analogy
- Learning by Example
- Discourse Management
- Partial Theory Formation

Theory Manipulation

- Theory Slicing, Merging
- Conflict Resolution
- Context Management
- Belief Management

Knowledge Content

Problem Solving & Reasoning Methods

Upper Ontology

- Mid-Level Theories

Domain-Specific Theories

Database

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Program Structure

- Operational challenge problem drives the desired R&D
- End-to-end teams solve problem
- Technology developers advance the state of the art

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Challenge Problem

- Develop knowledge bases to reason about chemical and biological weapons development

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Milestones

- FY 99 3Q BAA
- FY 00 1Q Awards
- FY 00 4Q Component Tests
- FY 01 Single User Entry
- FY 02 4Q Multi-User Entry
- FY 03 1M Axiom KB Developed

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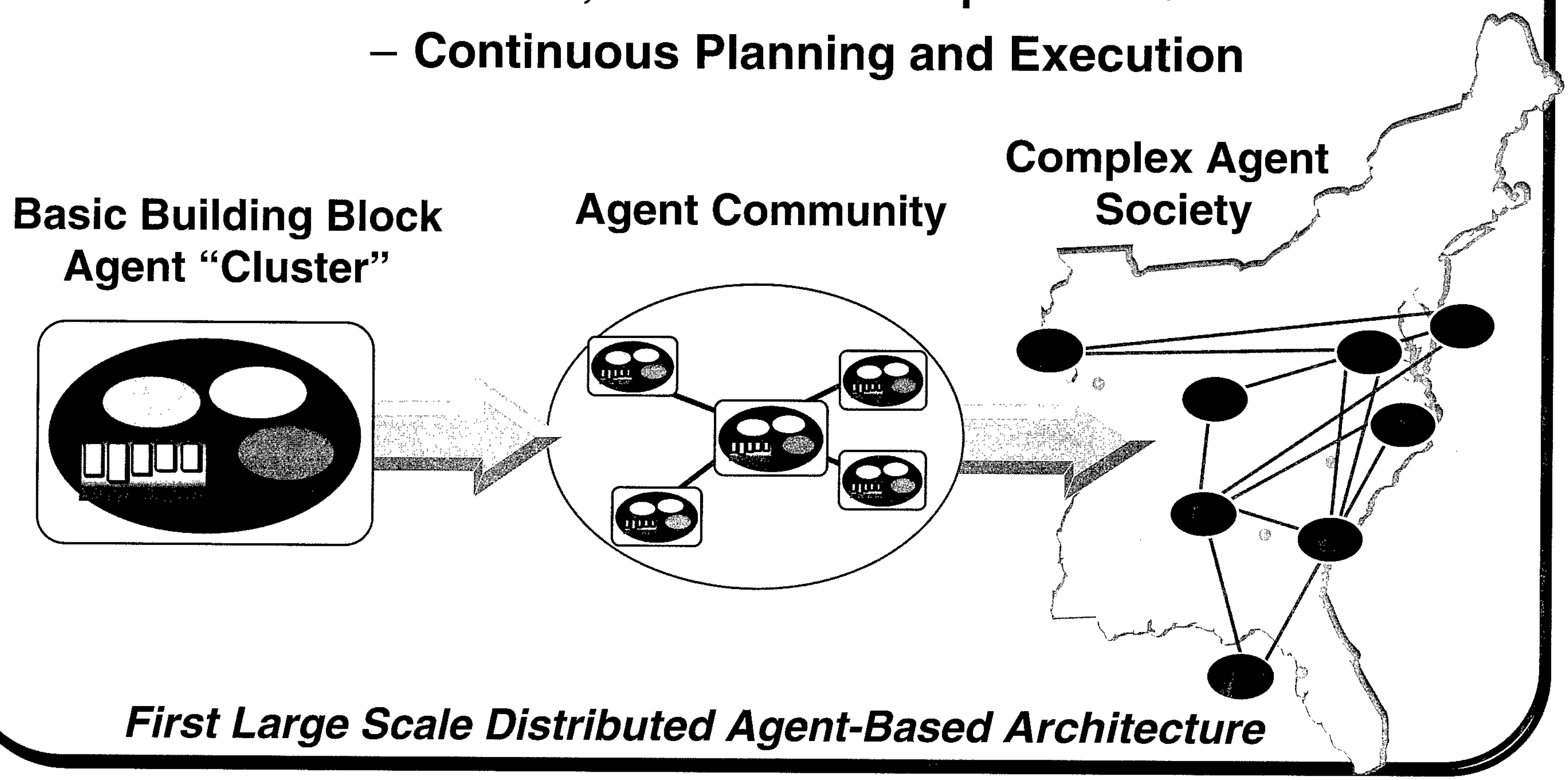
Advanced Logistics Project

Dr. Todd Carrico
Program Manager

Advanced Logistics Project

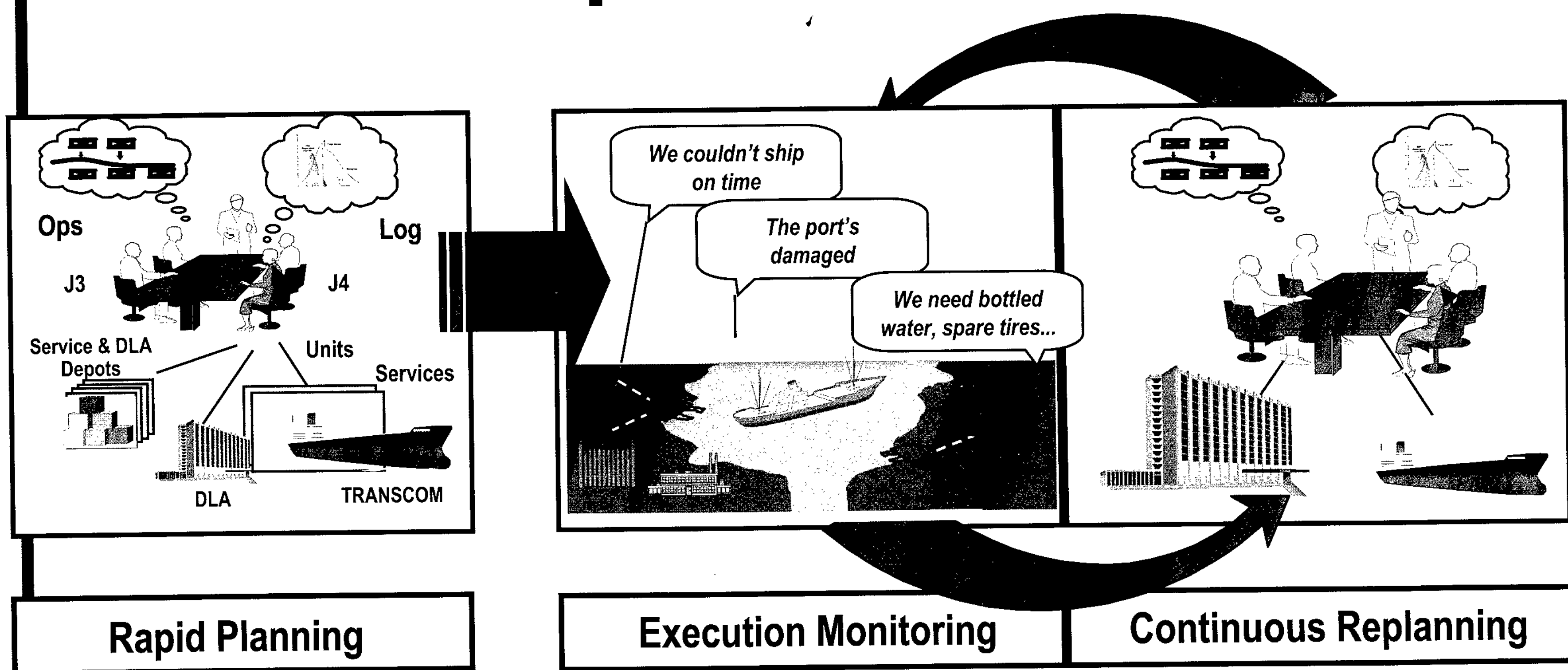
Getting Control of the Logistics Pipeline...

- Planning, Managing, and Providing Visibility
  - All Echelons, All Phases of Operations
    - Continuous Planning and Execution



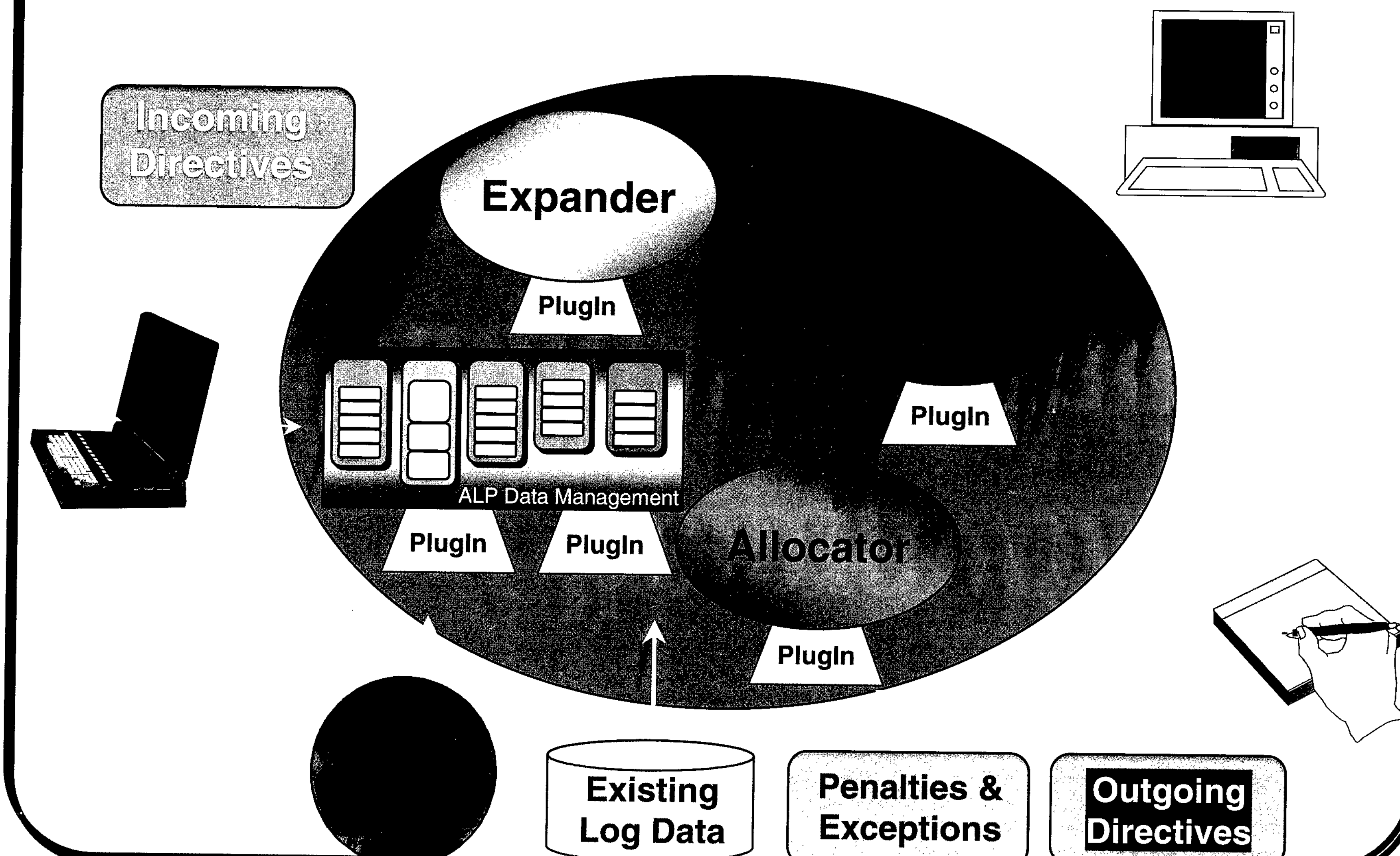
First Large Scale Distributed Agent-Based Architecture

ALP Operational Vision



- Continuous System
- Planning and Execution
- Extreme Detail

ALP Agent Cluster



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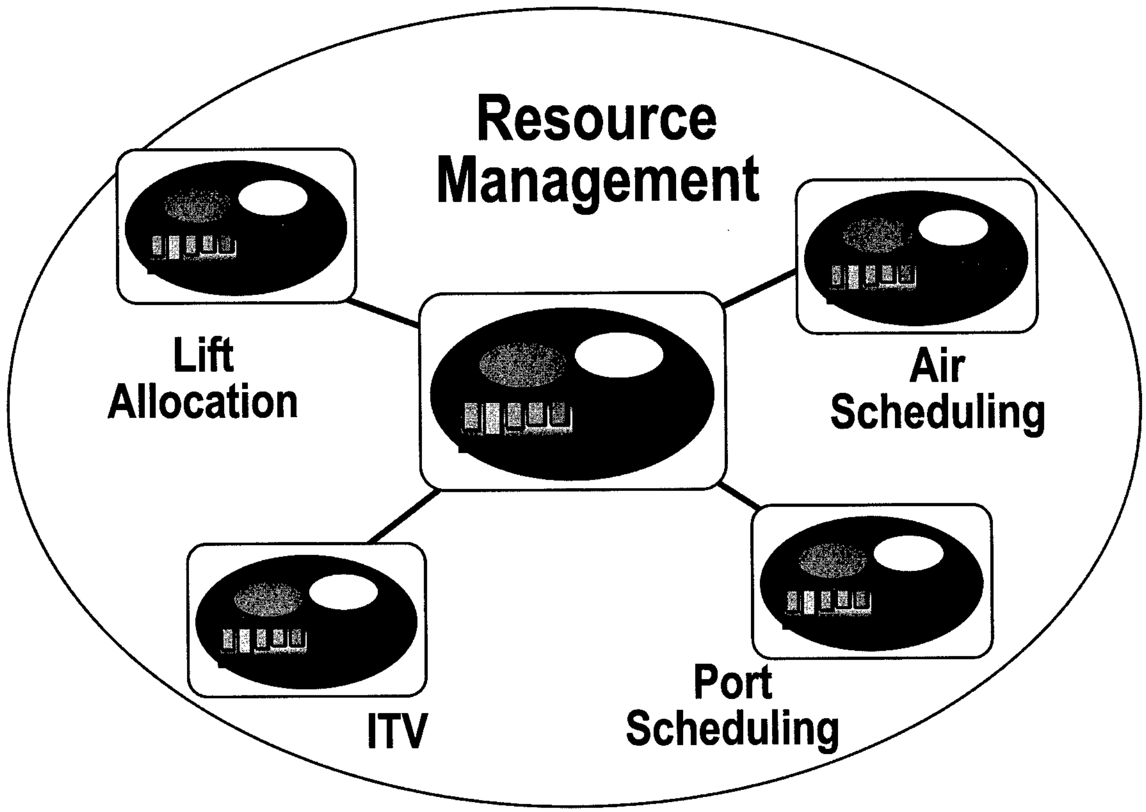
An ALP Community

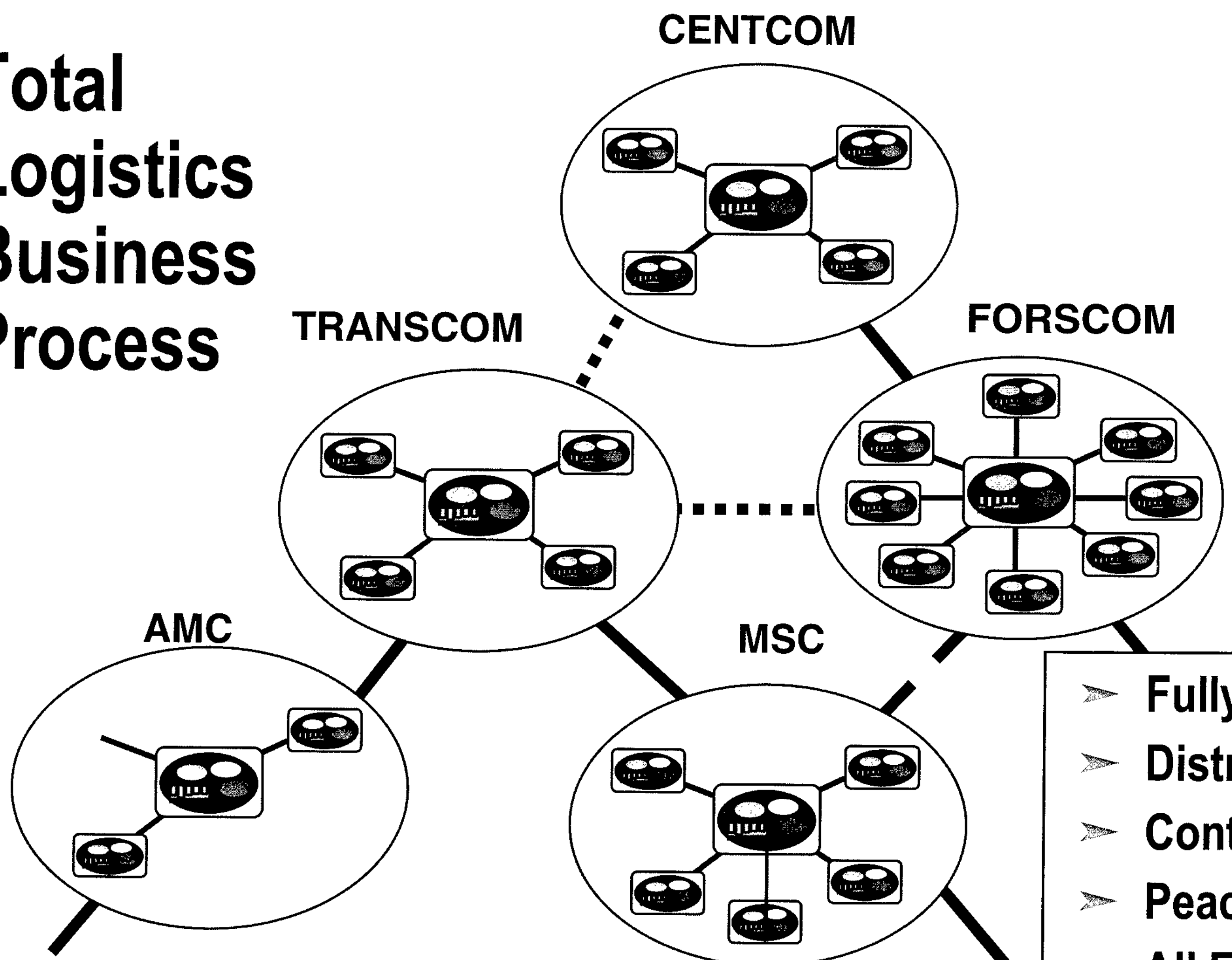
ISO



US Transportation Command

The ALP Society

Total Logistics Business Process



- Fully automated
- Distributed
- Continuous
- Peace and War
- All Echelons

DARPA ISO

Jan 99 Demo (FY98 Work)

Distributed logistics planning & execution system

- 5 Geographic sites
- Automatic information sharing using the Internet

Automatic generation of a detailed Logistics Plan

- Bottom-up demand generation
  - 70+ units and organizations
  - 800+ distinct processes
  - Unit level equipment item detail
- Live database access (JTAV, GTN, GDSS)
- Sustainment Support & Transportation schedules for
  - 10,000+ PAX
  - 2836 of the division's 8104 vehicles
  - 36 Tactical aircraft and support equipment
- Less than an hour

FY 99 Demo (Jan 00)

Larger Society

- 125 Clusters — 7 Geographic Locations
- 30 unique base plug-ins — 1200 specialized plug-ins

Larger Force Deployment

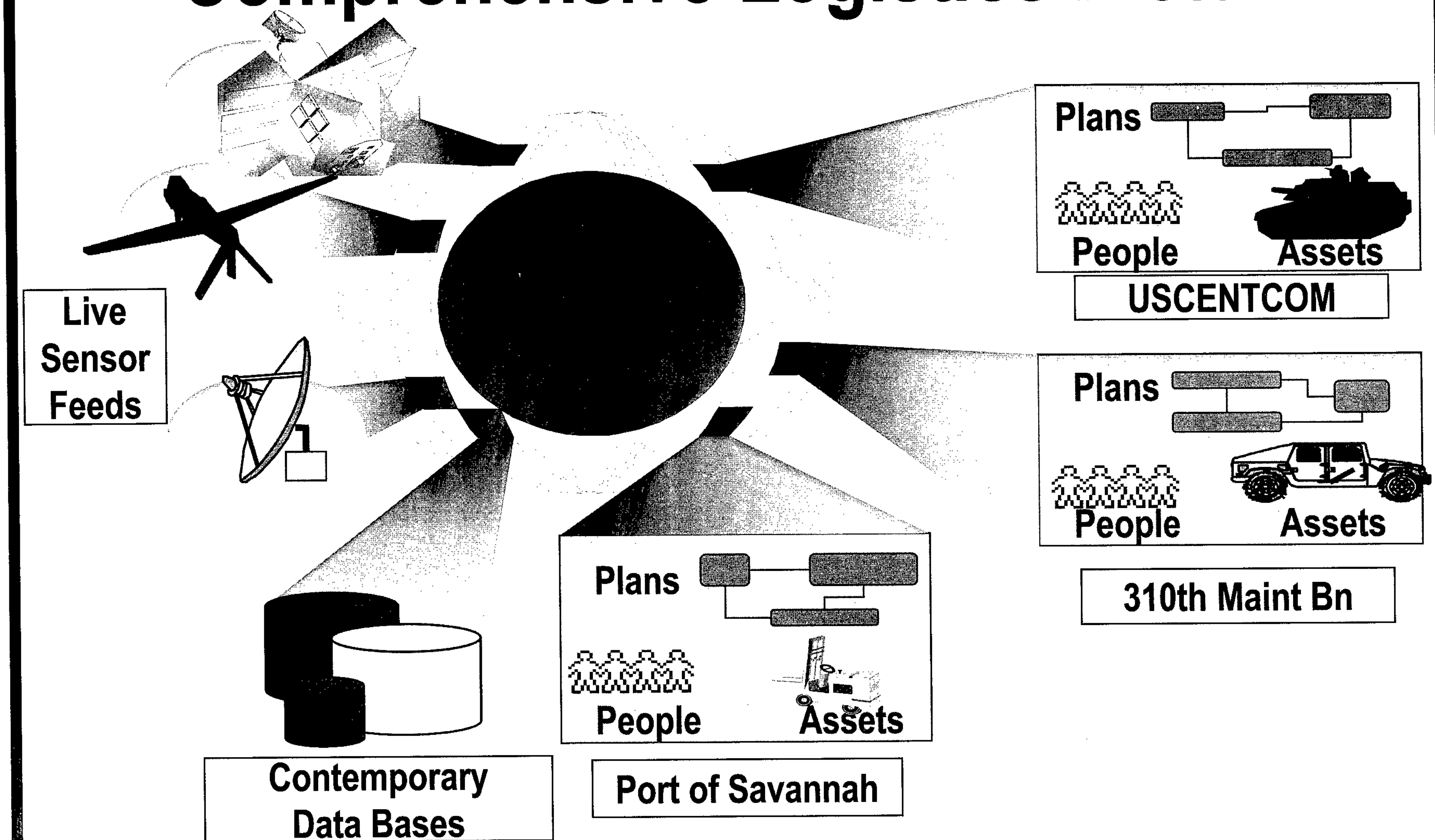
- Army Division / AF AEF Expansion
- Marine Expeditionary Force
- Numbered Navy Fleet (partial)

Planning from installation through TAA

Emphasis on Execution

- Monitoring execution against real-time data
- Sentinels identifying plan deviations
- Selective replanning to correct deviations

Comprehensive Logistics Picture



Integrates organizational plans, assets, real-world sensor data and databases

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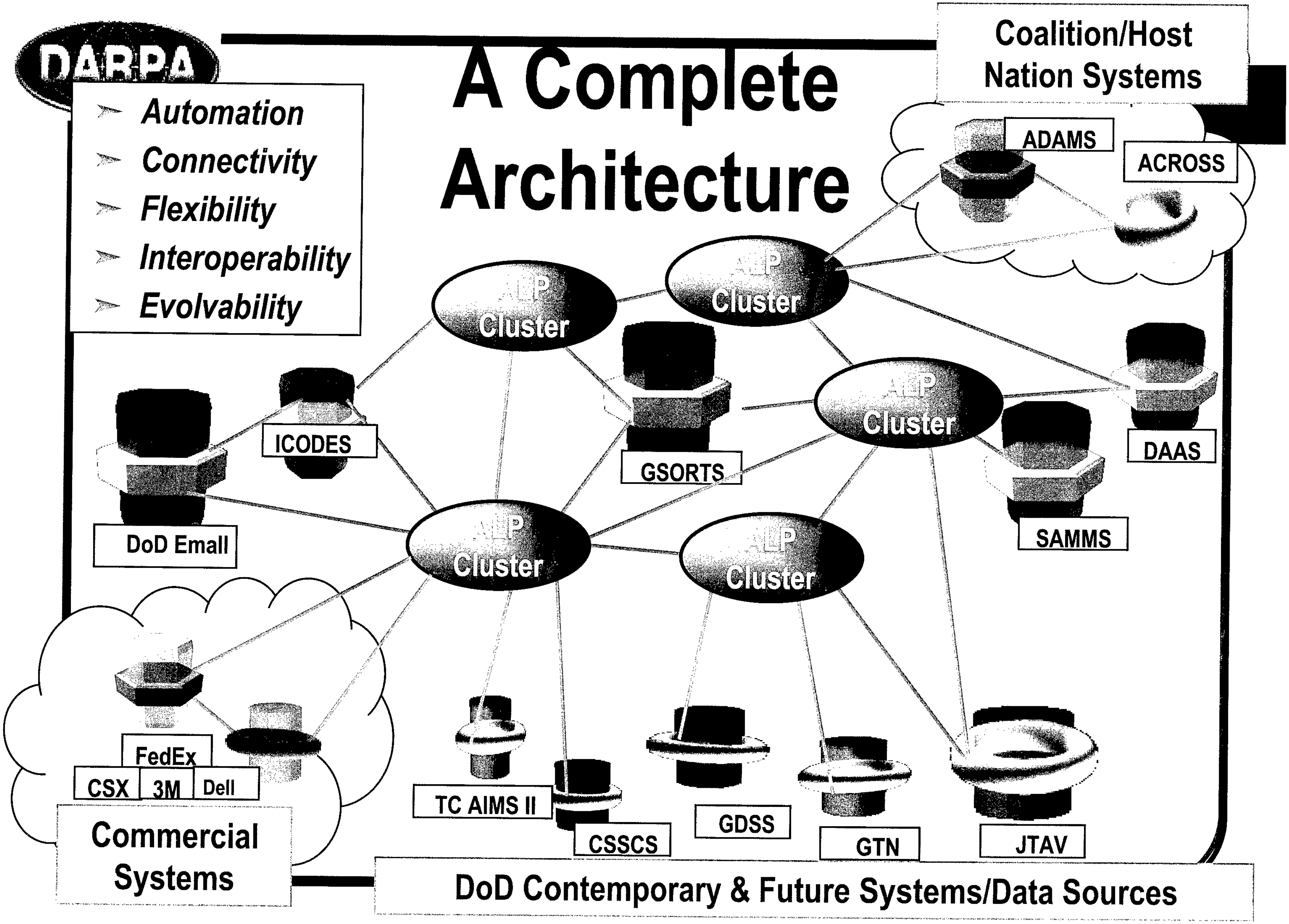
A Complete Architecture

- *Automation*
- *Connectivity*
- *Flexibility*
- *Interoperability*
- *Evolvability*



DARPATech '99

List of Acronyms

A

A/A	Air-to-Air
A/C	Aircraft
A/D	Analog-to-Digital
A/G	Air-to-Ground
AAN	Army After Next
AAV	Advanced Air Vehicle
ABCCC	Airborne Battlefield Command, Control and Communications
ABS	Agent-Based Systems
ACN	Airborne Communications Node
ACS	Adaptive Computing Systems
ACTD	Advanced Concept Technology Demonstration
ADC	Analog/Digital Converter
AEF	Air Expeditionary Force
AESA	Active Electronically Scanned Array
AF	Air Force
AFRL	Air Force Research Laboratory
AFSAB	Air Force Science Advisory Board
AFSS	Advanced Fire Support System
AI	Artificial Intelligence
a_i	Inference Agents
AIM	Advanced ISR Management
AIP	Automated Image Processing
AITS	Advanced Information Technology Services
AJ	Anti-Jamming; Active Jamming

ALP	Advanced Logistics Program; Advanced Logistics Planning
AMC	Army Materiel Command
AMD	Air Movement Device/Designator
AMEL	Active Matrix Electro-Luminescent
AMLCD	Active Matrix Liquid Crystal Display
AMRAAM	Advanced Medium-Range Air-to-Air Missile
AMSTE	Affordable Moving Surface Target Engagement
ANTS	Autonomous Negotiating Targets
AOE	Army of Excellence
AOR	Area of Operations
API	Application Program Interface
ARL	Army Research Laboratory; Aerial Reconnaissance Low
ARM	Advanced RISC Machine
ARPA	Advanced Research Projects Agency
a_s	Search Agents
ASARS	Advanced Synthetic Aperture Radar System
ASIC	Application Specific Integrated Circuit
ASIC	Application-Specific Integrated Circuit
ASSP	Application Specified Standard Product
ASTOVL	Advanced [Affordable] Short Takeoff and Vertical Landing
AT	Anti-Tank
AT3	Advanced Tactical Targeting Technology
ATD	Advanced Technology Demonstration
ATDNet	Advanced Technology Demonstration Network
ATM	Asynchronous Transfer Mode
ATO	Advanced Technology Office
ATR	Automatic Target Recognition
AVS	Airborne Video Surveillance
AWACS	Airborne Warning and Control System
AWEs	Advanced Warfighter Experiments

B

BAA	Broad Agency Announcement
BADD	Battlefield Awareness and Data Dissemination
BART	Bay Area Rapid Transit
BCTP	Battle Command Training Program
BDA	Battle Damaged Assessment
BG	Bacillus Subtilis Var Niger (biological warfare agent simulant)
BM	Ballistic Missile
BM/C3	Battle Management/Command, Control and Communications
BMC2	Battle Management Command and Control
bps	Bits per second
BW	Biological Warfare
BW/CW	Biological Warfare/Chemical Warfare
BWD	Biological Warfare Defense

C

C	Computer Programming Language
C^2	Command and Control
C^3	Command, Control and Communications
C^3	Command, Control and Communications
C^3I	Command, Control, Communications and Intelligence
C^4I	Command, Control, Communication, Computers and Intelligence
C^4ISR	C^4I and Surveillance and Reconnaissance
CAD	Computer Aided Design
CAF	Combat Air Force

CARS/DGS	Contingency Airborne Reconnaissance System/ Deployable Ground Station
CBD	Chemical/Biological Defense
CBS	Controlled Biological and Biomimetic Systems
CBW	Chemical/Biological Warfare
CC&D	Camouflage, Concealment and Deception
CCC&D	Counter-Camouflage, Concealment and Deception
CCD	Charged Coupled Devices
CCTT	Close Combat Tactical Trainer
CDL	Common Data Link
CDR	Critical Design Review
CECOM	Communications Electronics Command (Army)
CENTCOM	United States Central Command
CHPS	Combat Hybrid Power Systems
CIC	Combat Intelligence Center
CIDF	Common Intrusion Detection Framework
CINC	Commander in Chief
CISE	Computer and Information Science and Engineering
CKEM	Compact Kinetic Energy Missile
CLADS	Common Large Area Display Set
CM	Countermeasure
CM	Cruise Missile
CMD	Cruise Missile Defense
CMOS	Complementary Metal Oxide Semiconductor
CMP	Communication Module Processor
CNO	Chief of Naval Operations
COA	Course of Action
CoABS	Control of Agent Based Systems
COMINT	Communications Intelligence
COMMS	Communications Management System
COMSEC	Communications Security
CONOPS	Concept of Operations
CONUS	Continental United States
COP	Coefficient of Performance

CORBA	Common Object Request Broker Agent
COTS	Commercial Off-The-Shelf
CPE	Central Processing Element
CPoF	Command Post of the Future
CPU	Central Processing Unit
CRP	Collaborative Robot Platforms
CRT	Cathode Ray Tube
CRW	Canard Rotor/Wing
CS	Composable Services
CSAR	Combat Search And Rescue
CSSCS	Combat Service Support Control System
CTSS	Compatible Time Sharing System
CVGF	Counter Underground Facilities
CW Laser	Continuous Wave Laser
CW	Chemical Warfare

D

D	Dimensional (1-D; 2-D; 3-D; 4-D)
D/A	Digital-to-Analog
DARPA	Defense Advanced Research Projects Agency
DB	Database
DC	Direct Current
DDB	Dynamic Database
DEMUX	Demultiplexor
DFB	Distributed Feedback
DI	Deionized (water)
DIA	Defense Intelligence Agency
DII	Defense Information Infrastructure; Discoverer II
DIRO	Director's Office
DISA	Defense Information Systems Agency

DISN	Defense Information Systems Network
DLA	Defense Logistics Agency
DLP	Digital Light Processing
DMD	Digital Micromirror Device
DMZ	Demilitarized Zone
DNA	Deoxyribonucleic Acid
DNS	Domain Name Server
DoD	Department of Defense
DOE	Department of Energy
DoS	Denial of Service
dpi	Dots Per Inch
DRaFT	Digital Radio Frequency Tag
DRAM	Dynamic Random Access Memory
DREN	Defense Research and Engineering Network
DSB	Defense Science Board
DSO	Defense Sciences Office
DSP	Digital Signal Processor
DTED	Digital Terrain Elevation Data

E

E/O	Electro-Optical
EAP	Electroactive Polymers
ECCM	Electronic Counter-Countermeasures
EL	Electro-Luminescent
ELF/VLF	Extremely Low Frequency/Very Low Frequency
ELINT	Electronic Intelligence
ELO	Epitaxial Lateral Overgrowth
ELS	Emitter Location System
EM	Electromagnetic; Electrothermal Magnetic
EMC	Electromagnetic Compatibility

EMD	Engineering and Manufacturing Development; Engineering Manufacturing Design
EMI	Electromagnetic Interference
EMP	Electromagnetic Pulse
ENG	Electronic News Gathering
EO	Electro-Optical
EO/IR	Electro-Optical/Infra-Red
EPLRS	Enhanced Position Location Reporting System
ESA	Electronically Scanned Array
ESNET	Energy Sciences Network
ETC	Electrothermal Chemical
ETDM	Electronic Time Division Multiplexing
ETO	Electronic Technology Office (now MTO)
ETRAC	Enhanced Tactical Radar Correlator
EV	Electric Vehicle
EW	Electronic Warfare

F

F	Frequency
FA	False Alarm
FAO	Foreign Area Officer
FBE	Fleet Battle Experiment
FDDI	Fiber Distributed Data Interface
FDOA	Frequency Difference of Arrival
FED	Field Emission Display
FET	Field Effect Transistor
FFT	Fast Fourier Transform
FIR	Far Infrared; Finite Impulse Response
FOPEN	Foliage Penetration
FORSCOM	United States Army Forces Command
FPA	Focal Plane Array

FPGA	Field Programmable Gate-Array
FTE	Full Time Employment
FY	Fiscal Year

G

G/T	antenna Gain-to-noise Temperature
GBR	Ground Based Radar
GBS	Global Broadcast Service
GDSS	Global Decision Support System
GFI	Government Furnished Information
GGP	GPS Guidance Package
GMR	Giant Magneto Resistance
GMTI	Ground Moving Target Indicator
Gnd	Ground
GOTS	Government Off-The-Shelf
GPS	Global Positioning System
GPS/INS	Global Positioning System/Inertial Navigation System
GS	General Service
GTN	Global Transportation Network

H

H/W	Hardware
HAE	High Altitude Endurance
HAE UAV	High Altitude Endurance Unmanned Air Vehicle
HARM	High-speed AntiRadiation Missile
HCI	Human Computer Interaction
HD	Hard Drive
HDS	High Definition Systems

HEV	Hybrid Electric Vehicle
HF	High Frequency
HP	Horsepower
HPC	High-Performance Computing
HPCC	High Performance Computing and Communications
HPKB	High Performance Knowledge Base
HRI	Human Robot Interface
HRR	High Range Resolution
HSCC	High Speed Connectivity Consortium
HTS	High Temperature Superconductors
HTTP	HyperText Transfer Protocol
HVAC	High Voltage Alternating Current
HW	Hardware

I

I&T	Integration and Test
I&W	Indications and Warning
I/O	Input/Output
IA	Information Assurance
IC	Integrated Circuit
ICE	Independent Cost Estimate
ICMP	Internet Control Message Protocol
ICS	Integrated Communications System
IEEE	Institute of Electrical and Electronics Engineers
IER	Interim Evaluation Review
IETF	Internet Engineering Task Force
IFF	Identification, Friend or Foe
IIOP	Internet Inter-ORB Protocol
IMINT	Imagery Intelligence
IMU	Inertial Measurement Unit
INS	Inertial Navigation System

IP	Internet Protocol
IPB	Intelligence Preparation of the Battlefield
IR	Infrared; Information Retrieval
IS	Information System; Intelligent System
ISO	Information Systems Office
ISP	Internet Service Provider
ISR	Intelligence, Surveillance and Reconnaissance
IT	Information Technology
ITO	Information Technology Office
ITS	Interactive Training System
ITV	In Transit Visibility
IU	Image Understanding
IUFP	Image Understanding for Force Protection
IW	Information Warfare

J

JFACC	Joint Forces Air Component Commander
JIP	Just In time Power
JL-ACTD	Joint Logistics Advanced Concept Technology Demonstration
JPO	Joint Program Office
JRP	Joint Robotics Program
JSF	Joint Strike Fighter
JSTARS	Joint Surveillance Target Attack Radar System
JTAV	Joint Total Asset Visibility
JTF	Joint Task Force
JTIDS	Joint Tactical Information Distribution System
JV	Joint Vision

K

KB	Knowledge Base
KE	Kinetic Energy

L

LADAR	Laser Radar
LAN	Local Area Network
LCCMD	Low Cost Cruise Missile Defense
LED	Light-Emitting Diode
LNA	Low Noise Amplifier
Log	Logistics
LOS	Loss of Signal; Line of Sight
LPD	Low Probability of Detection
LSB	Least Significant Bit
LTTE	Liberation Tigers of Tamil Eelam (Sri Lanka)
LWIR	Long Wavelength Infrared

M

MAFC	Micro Adaptive Flow Control
MAFET	Microwave and Analog Front-End Technology
MALD	Miniature Air Launched Decoy
MARS	Mobile Autonomous Robot Software
MAV	Micro Air Vehicles
MBT	Main Battle Tank
MCM	Mine Countermeasures; Multi-Chip Module
MCU	Master Control Unit

MDARS	Mobile Detection Assessment Response Team
MDV	Minimum Detectable Velocity
MEDLINE	MEDLARS On-Line System
MEF	Marine Expeditionary Force
MEMS	Microelectromechanical Systems
MGM	Minimally Guided Munitions
MICE	Mesoscopic Integrated Conformal Electronics
MIMIC	Microwave and Millimeter Wave Monolithic Integrated Circuits
MIPS	Million Instructions Per Second
MIPS	Millions of Instructions Per Second
MMCS	Multi-Mission Combat Systems
MMIC	Monolithic Microwave Integrated Circuit; Miniature Millimeter Wave Integrated Circuit
MOA	Memorandum of Agreement
MONET	Multiwavelength Optical Networking
MOPS	Million Operations Per Second
MOS	Metal Oxide Semiconductor
MPRF	Medium Pulse Repetition Frequency
MPU	Microprocessor Unit
MS	Milestone
MSB	Most Significant Bit
MSE	Mobile Subscriber Equipment
MSET	Multi-Sensor Exploitation Testbed
MSTAR	Moving and Stationary Target Acquisition and Recognition
MT	Machine Translation
MTBF	Mean-Time-Between-Failure
MTI	Moving Target Indication
MTO	Microsystems Technology Office
MUC	Message Understanding Conference
MULTICS	Multiplexed Information and Computing Service
MUX	Multiplexor

N

NAS	Naval Air Station
NASA	National Aeronautics and Space Administration
NATO	North Atlantic Treaty Organization
NAWC	Naval Air Warfare Center
NB	Narrow Band
NGI	Next Generation Internet
NIH	National Institute of Health
NII	National Information Infrastructure
NIMA	National Imagery and Mapping Agency
NIST	National Institute of Standards and Technology
NLM	National Library of Medicine
NREN	National Research and Education Network
NRL	Naval Research Laboratory
NRO	National Reconnaissance Office
NSA	National Security Agency
NSF	National Science Foundation
NT	Nodal Terminal
NTONII	National Transparent Optical Network
NVESD	Night Vision and Electronic Sensors Directorate

O

O	Output
O&S	Operations and Support
OCP	Open Control Platform
OCR	Optical Character Resolution
OEIC	Optoelectronic Integrated Circuit
OLED	Organic Light Emitting Diode

ONR	Office of Naval Research
ONRAMP	Optical Network for Regional Access using Multiwavelength Protocols
OO	Object Oriented
OODA	Observe, Orient, Decide, Act
OOTW	Operations Other Than War
Ops	Operations; Operations per second
ORB	Object Request Broker
OS	Operating System
OSD	Office of the Secretary of Defense
OTDM	Optical Time Division Multiplexing
OXC	Optical (WDM) Cross-Connect

P

P	Power
PA	Power Amp
PAC/C	Power Aware Computing and Communications
PACOM	U.S. Pacific Command
PACT	Photonic A/D Converter Technology
PAX	Passengers
PC	Personal Computer
PCC	Proof-Carrying Code
PCR	Polymerase Chain Reaction
PCS	Personal Communications System
PDR	Preliminary Design Review
PESA	Passive Electronically Scanned Array
PFCT	Precision Fire Control Tracking
PGM	Precision-Guided Munition
PILOT	Phase Integrated Laser Optics Technology
Pk	Probability of Kill
PM	Passive Matrix; Program Manager

PNP	Positive-Negative-Positive
POC	Point of Contact
PR	Preliminary Review
PRDA	Program Research and Development Activity
PRF	Pulse Repetition Frequency
PRI	Primary Rate Interface
PS	Phase Shifters
PTCOE	Phosphor Technology Center of Excellence
P-V-T	Position-Velocity-Time
PVTF	Position-Velocity-Time-Frequency

Q

Q	Quarter

R

R&D	Research and Development
R/T	Receive/Transmit
RADANT	Radome Antenna
RADAR	Radio Detecting/Detection and Ranging
RAM	Random Access Memory
RF	Radio Frequency
RFP	Request for Proposals
RIN	Relative Intensity Noise
RISC	Reduced Instruction Set Computing
RKF	Rapid Knowledge Formation
RNA	Ribonucleic Acid
ROM	Rough Order of Magnitude
RPV	Remotely Piloted Vehicle

RSS	Radar Signal Simulator; Radar Support System
RST-V	Reconnaissance, Surveillance, and Targeting Vehicle
RTIP	Real Time Interactive Processor
RX	Receive; Receiver

S

S&T	Science and Technology
S/V	Survivability/Vulnerability
S/W	Software
SAIP	Semi-Automated Image Processing
SAM	Surface-to-Air Missile
SAR	Synthetic Aperture Radar
SATCOM	Satellite Communications
SBIR	Small Business Innovative Research
SBR	Space-Based Radar
SDR	Software for Distributed Robotics
SEAD	Suppression of Enemy Air Defenses
SEC	Software Enabled Control
SHM	Self-Healing Minefield
SI	System Integration; International System of Units
SIGINT	Signals Intelligence
SIL	Systems Integration Lab
SINGARS	Single-Channel Ground and Airborne Radio System
SLID	Small Low-Cost Interceptor Device
SMPTE	Society of Motion Picture and Television Engineers
SNMP	Simple Network Management Protocol
SNR	Signal-to-Noise Ratio
SOF	Special Operations Forces
SOFT	Self Orienting Fluidic Transport
SONET	Synchronous Optical Network

SPARC	Scalable Processor Architecture
SPO	Special Projects Office
SQUID	Superconducting Quantum Interference Devices
SRAM	Static Random Access Memory
SSCOM	Soldier System Command
SSN	Ship, Submersible, Nuclear
STALO	Stable Local Oscillator
STAP	Space-Time Adaptive Processing
STAR	Simultaneous Transmit And Receive
STO	Sensor Technology Office (now SPO)
SUO	Small Unit Operations
SW	Software; Short Wave
SWAP	Size, Weight, Area and Power
SWIR	Short Wavelength Infrared

T

T	Temperature; Time
T/R	Transmit/Receive
TAA	Technology Assistance Agreement
TACOM	Tank and Automotive Command
Tags/MGM	Tags/Minimally Guided Munitions
TC AIMS II	Transportation Coordinators Automatic Information for Movement System II
TCDL	Tactical Common Data Link
TDOA	Time Difference of Arrival
TDT	Topic Detection and Tracking
TEL	Transporter Erector Launcher
TES	Tactical Exploitation Station
TFEL	Thin Film Electro-Luminescent
TFT	Thin Film Transistor
TI	Technology Independent; Test Interface

TIA	Total Information Awareness
TIDES	Translingual Information Detection, Extraction, and Summarization
TIE	Technology Integration Experiment
TLE	Target Location Error
TMD	Theater Missile Defense
TMR	Tactical Mobile Robotics
TMR	Tactical Mobile Robotics
TNT	Trinitrotolouene
TOA	Time of Arrival
TPV	Thermophotovoltaics
TRANSCOM	U.S. Army Transportation Command
TRANSEC	Transmission Security
TREC	Text Retrieval Conference
TTO	Tactical Technology Office
TWR	Trans World Radio
TX	Transmit; Transmitter

U

UAV	Unmanned Air Vehicle
UCAV	Unmanned Combat Aerial Vehicle
UGF	Underground Facilities
UGS	Unattended Ground Sensor
UGV	Unmanned Ground Vehicle
UHF	Ultra High Frequency
UNIX	Uniplexed Information and Computing Service
USA	United States Army
USAF	United States Air Force
USAR	United States Army Reserve
USCG	United States Coast Guard
USMC	United States Marine Corps

USN	United States Navy
UWB	Ultra Wideband
UXO	Unexploded Ordnance

V

vBNS	Very high performance Backbone Network Service
VCO	Voltage Controlled Oscillator
VCSELs	Vertical Cavity Surface Emitting Lasers
VDoP	Vertical Dilution of Precision
VHF	Very High Frequency
VLSI	Very Large Scale Integration
VSP	Vehicle Self Protection
VTOL	Vertical Take-Off and Landing

W-Z

WAN	Wide Area Network
WB	Wide Band
WDM	Wavelength Division Multiplexing
WSTS	Weapon System Trade Study
WT	Weight
WWW	World Wide Web